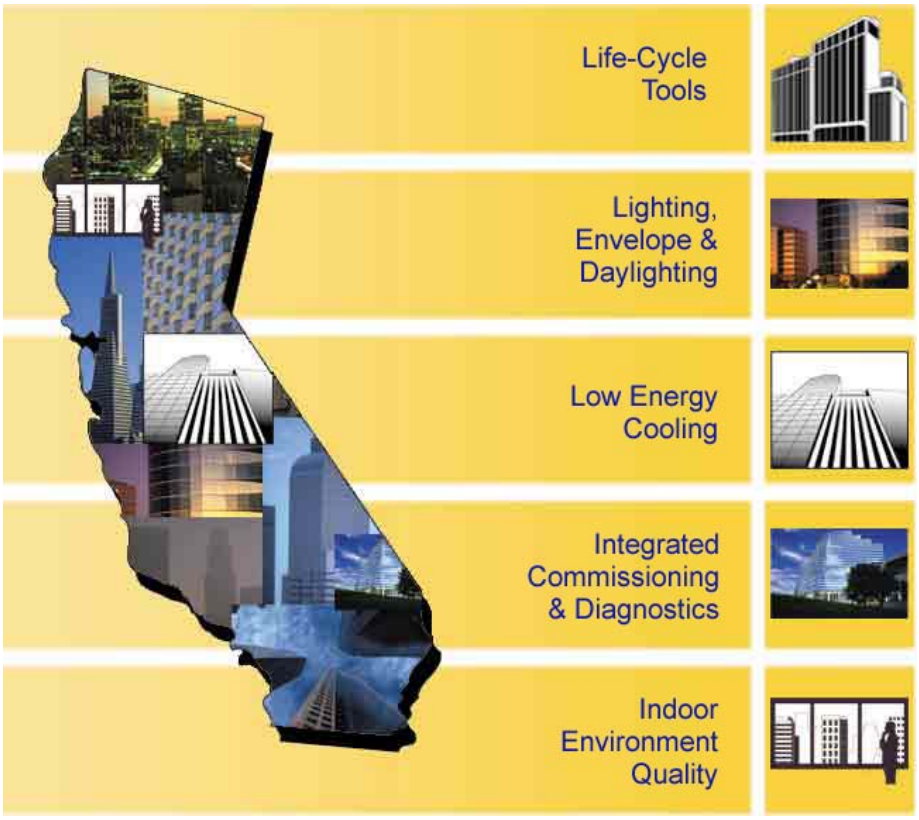
CALIFORNIA
ENERGY
COMMISSION

Low Energy Cooling System Appraisals



TECHNICAL REPORT

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CALIFORNIA ENERGY COMMISSION

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Program's final report and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the High Performance Commercial Building Systems (HPCBS) Program. This Commercial Building Energy Benchmarking attachment provides supplemental information to the final report (Commission publication # 500-03-097-A2). The reports, and particularly the attachments, are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This document is the seventh of 22 technical attachments to the final report, and consists of a research report:

- Low Energy Cooling System Appraisal Study (E4P2.1T2a)

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced this document as part of a multi-project programmatic contract (#400-99-012). The Buildings Program includes new and existing buildings in both the residential and the nonresidential sectors. The program seeks to decrease building energy use through research that will develop or improve energy-efficient technologies, strategies, tools, and building performance evaluation methods.

For the final report, other attachments or reports produced within this contract, or to obtain more information on the PIER Program, please visit http://www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. The reports and attachments are also available at the HPCBS website: http://buildings.lbl.gov/hpcbs/.

Abstract

Low Energy Cooling System Appraisal Study

An appraisal of the potential performance of different Low Energy Cooling (LEC) systems in non-residential buildings in California has been conducted using computer simulation. The report presents results from the first phase of the study, which addressed the systems that can be modeled with the DOE-2.1E simulation program, and from the second phase, in which additional systems were simulated using EnergyPlus. Graphical comparisons of the performance of different systems in four populous climates, represented by Oakland, Sacramento, Pasadena and San Diego are presented and interpreted. Detailed results are presented in tabular form for the 16 California climate zones. The report documents the design and modeling assumptions used in the study and makes recommendations for further work.

California Energy Commission
Public Interest Energy Research Program

HPCBS # E4P2.1T1b

HPCBS

High Performance Commercial Building Systems

Low Energy Cooling System Appraisal Study: Phase I – Results of DOE-2 Simulations

Element 4 - Low Energy Cooling
Project 2.1 - Appraisal of System Configurations

Norman Bourassa, Philip Haves and Joe Huang
Lawrence Berkeley National Laboratory
July, 2003

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Low Energy Cooling System Appraisal Study: Phase I – Results of DOE-2 Simulations

Norman Bourassa, Philip Haves and Joe Huang, LBNL

July 15, 2003

Abstract

An appraisal of the potential performance of different Low Energy Cooling (LEC) systems in non-residential buildings in California is being conducted using computer simulation. The paper presents results from the first phase of the study, which addressed the systems that can be modeled, with the DOE-2.1E simulation program.

The following LEC technologies were simulated as variants of a conventional variable-air-volume system with vapor compression cooling and mixing ventilation in the occupied spaces:

- air-side indirect and indirect/direct evaporative pre-cooling
- cool beams
- displacement ventilation

Results are presented for the 16 California thermal climate zones. The greatest energy savings are obtained from a combination of displacement ventilation and air-side indirect/direct evaporative pre-cooling. Cool beam systems have the lowest peak demand but do not reduce energy consumption significantly because the reduction in fan energy is offset by a reduction in air-side free cooling. Overall, the results indicate significant opportunities for LEC technologies to reduce energy consumption and demand in non-residential new construction and retrofit.

Introduction and Scope of the Study

The aim of this simulation appraisal of Low Energy Cooling (LEC) system configurations is to assess their potential for use in the 16 California climate zones. Phase I addresses those technologies that can be modeled with the DOE-2.1E building energy simulation tool. Phase II will include additional systems that can be simulated using more detailed models to be developed for EnergyPlus in the parallel *Tools and Guides* Project of the High Performance Commercial Building Systems program.

Cooling of Commercial Buildings in California

Space cooling in commercial buildings in California accounts for ~5% of the state's total annual electrical energy consumption, i.e. ~14,000 MWh in 1999 (Brown et al. 2002). The peak demand in 1999 was 7.1 GW, which is ~14% of the total for the state. There is significant potential to reduce this consumption, since the conventional HVAC systems that provide most of this cooling typically do not take full advantage of the climate conditions in California.

Low Energy Cooling Systems

Low energy cooling systems use a variety of approaches, either singly or in combination, to reduce the energy consumption and peak demand associated with the cooling of occupied spaces:

- **Eliminate or reduce chiller use** - dissipating heat directly to the environment, e.g. evaporative cooling, natural ventilation
- **Cool spaces more effectively -** allowing higher temperature air or water to be supplied to condition the space, e.g. displacement ventilation, radiant cooling
- **Shift/smooth peak demand with thermal mass** – increase the effectiveness of pre-cooling and load smoothing using exposed slabs and raised floors
- **Improve distribution system efficiency** – reduce leakage and thermal losses from duct systems or use water instead of air to reduce parasitic losses

Many of these technologies hold the promise of significantly lower energy consumption and electricity demand. However, they are often quite sensitive to climate conditions. The aim of the study reported here is to assess the energy and peak demand performance in California climates, for those low energy cooling (LEC) systems that can be simulated adequately using the DOE-2.1E simulation program (Winklemann et al. 1993). These systems are:

- **Indirect/Direct Evaporative Cooling -** ventilation air is cooled either by direct evaporation into the air stream or by evaporation into an air stream that is coupled to the ventilation air stream via a heat exchanger – see Figure 1. Five combinations were modeled:
  - Direct only
  - Indirect only (outside air on wet side)
  - Indirect/direct (outside air on wet side)

- **Cooled Beams** - the occupied space is cooled by circulating cool water through exposed fin-tubes in the ceiling – see Figure 2. The temperature of the water is significantly higher than in conventional air systems, allowing greater direct use of cooling towers to reduce the use of refrigeration systems. This assumes that any latent load is met by dehumidifying the outside air supplied to meet the minimum ventilation requirement. The output of cool beams is mainly convective and their position in the ceiling results in mixing of the air in the space. Modeling of cool beams is described by Winklemann et al. (2000)

- **Displacement Ventilation -** air is supplied at floor level and at low velocity to avoid mixing – see Figure 3. The effective comfort temperature is approximately mid way between the supply and extract temperatures, so higher supply air temperatures can achieve the same level of comfort, allowing refrigeration system use to be reduced or eliminated. As regards thermal performance, displacement ventilation can be considered to be a limiting case of underfloor air distribution in which there is negligible low-level mixing.

Figure 4 shows the baseline system, which is a conventional built-up variable-air-volume system with vapor compression cooling and mixing ventilation in the occupied spaces.

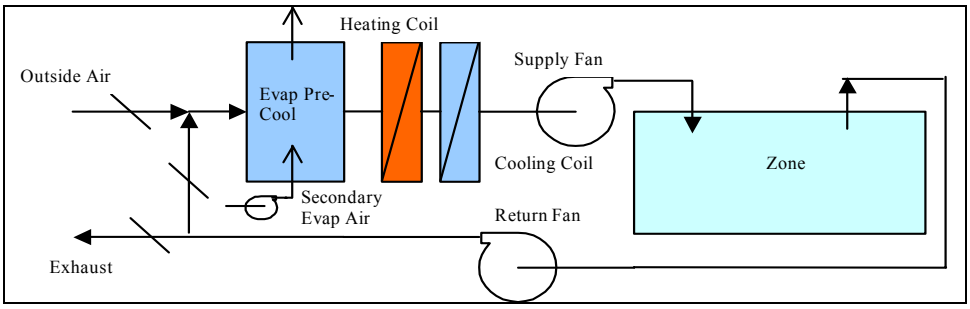

Figure 1: Simplified schematic of evaporative pre-cool on a vapor compression system

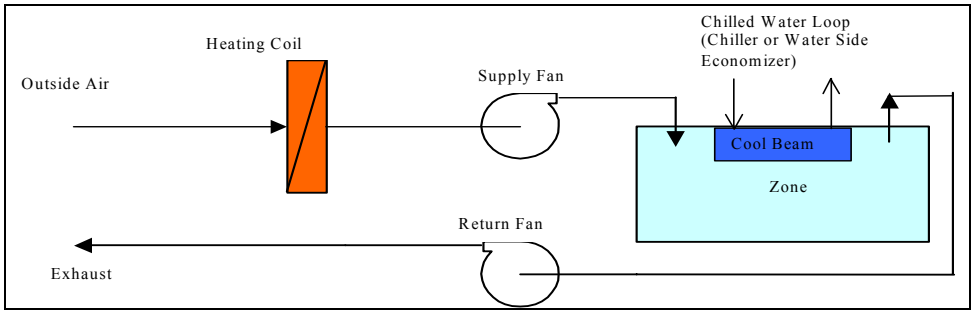

Figure 2: Simplified schematic of a cool beam system

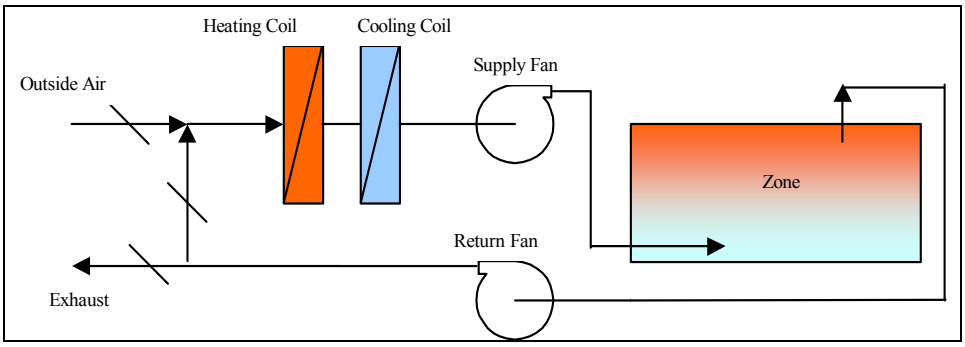

Figure 3: Simplified schematic of displacement ventilation with vapor compression system

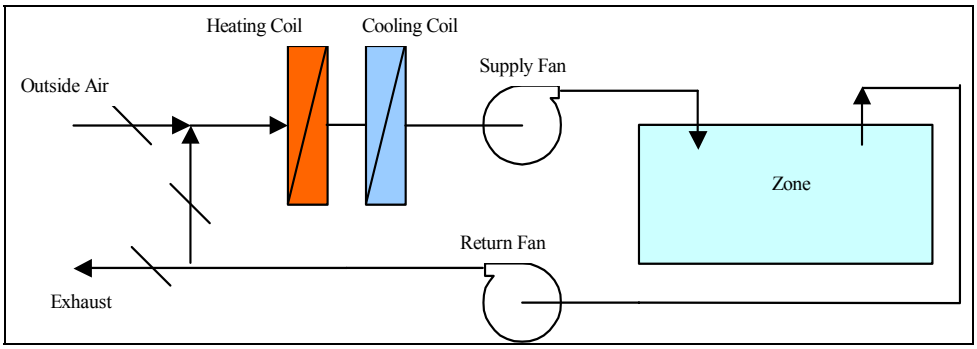

Figure 4: Simplified schematic of the baseline vapor compression built-up system

Building Types & Model Parameters

Study Methodology

The DOE2.1E simulation program (Winkelmann et al. 1993) was used to calculate the relative savings potential of the chosen LEC systems. Since DOE2 was not designed to treat situations in which the zone temperature set-point is not met, modeling was limited to LEC systems that involve additions or modifications to a compressor-based system. Stand-alone systems will be examined using EnergyPlus in a follow-on study.

The purpose of the study reported here was to assess the generic potential of different cooling systems, by predicting their relative performance under a range of conditions chosen as representative of broad classes of buildings. For a particular design brief, the results can be used to generate a short list of cooling system types worthy of further evaluation but should not be used to predict the actual performance that would be obtained from a real building constructed to a specific design and operating under particular conditions.

There are a number of potentially synergistic combinations of the systems listed above. Evaporative cooling complements displacement ventilation because evaporative cooling can more easily achieve the higher supply air temperature required by displacement ventilation. Cool beams are not compatible with displacement ventilation because they produce mixing of the air in the space that disrupts the thermal stratification that is a key attribute of displacement ventilation.

A simplified approach to modeling displacement ventilation was adopted for use with DOE-2.1E. A conventional load calculation is performed and then the supply air temperature is increased from 55°F to 65°F and the zone air temperature set-point is increased from 74°F to 84°F for the Systems and Plant calculations. Since DOE-2 can only model spaces as fully mixed, raising the zone air temperature is the only way to raise the extract temperature. This approach is based on the assumption that, in a displacement system, the dry bulb temperature averaged over the height range of a sedentary person is depressed below the extract temperatures by ~60% of the difference between the supply and extract temperatures (Nielsen 1996). Since the predicted savings for displacement ventilation systems reported below are substantial, additional simulations were performed with a supply air temperature of 60°F and a return air temperature of 84°F. These temperatures are similar to those used in designing underfloor air distribution systems with swirl diffusers, a commonly installed system in new office buildings.

Building Types

Rather than simulate a number of different building forms, a generic multi-storey building model was used. This approach was taken after feedback from practicing design engineers at a meeting held to review this work. Their recommendation was to represent different building configurations by varying the occupancy period and the minimum outside air fraction as shown in Table 1, which shows the generic building types that correspond to the combinations of occupancy period and ventilation level that were simulated. The design engineers envisaged that the results could provide them with a quick assessment of the potential applicability of LEC systems during schematic design.

The base model is a modified version of the large office DOE2.1E prototypical model developed in a previous energy analysis study of HVAC systems (Huang, et al. 1999; Huang, 1999). The building has six storeys and a basement, with a total adjusted floor area of 105,000 sf, and the total number of occupants is 354. On the recommendation of the design engineers, the six main floors have a plug load density of 2.5 W/sf in the base case. The lighting power density of 1.2 W/sf was selected to satisfy California's Title-24 Building Standard. All four versions of the model shown in Table 1 have the same internal load densities. The building envelope characteristics were selected to satisfy the requirements of Title-24 in the climate zone being simulated.

Table 1: Occupancy/ventilation regimes covered in the study

	Economizer: 15% Minimum Outside Air	**100% Outside Air, No Economizer**
12 Hour Occupancy	Commercial Offices Retail	Laboratory
24 Hour Occupancy	Hotels Supermarkets High Rise Residential	Hospitals

Simulation Parameters

Parametric runs have been performed for each possible combination of:

- Building occupancy/ventilation regime (given in Table 1)
- Cooling system (conventional and the low energy systems and system combinations described in the Appendices)
- Climate (16 representative California climates as defined by the CEC) (The original Title-24 weather files for representative cities were used in preference to the synthetic averaged weather for each climate zone developed in 1992 and now used for Title-24 compliance, since they contain weather data from actual locations within each climate zone rather than hypothetical average conditions in each climate zone that are not indicative of the weather in any specific location.)
- Cooling load as determined by the envelope and lighting system. Two levels of equipment loads have been modeled in all cases:
  - 2.5 W/sf, which is considered to be representative of the level designers need to assume in order to allow for uncertainty in the actual usage and to meet client expectations
  - 1.0 W/sf, which is considered to be more representative of actual equipment loads in commercial offices
- Two levels of thermal mass exposure to the space.

Initially three levels of cooling load were modeled for each building occupancy/ventilation regime. The three levels correspond to:

- Compliance with Title-24
- Current Best Practice in California.
- Premium Energy Efficiency – use of the best available envelope and lighting system components

A review of the initial results indicated insignificant variation in the *relative* performance of different cooling systems for the three levels. This can be taken to indicate that the current version of Title 24 imposes a relatively high standard for the envelope and lighting and that system selection will, in general, not be affected by improvements in the envelope and lighting systems that are based on conventional practice and economic considerations. As result, all subsequent simulations where performed with only Title-24 compliant construction and lighting power density.

The window characteristics are shown in Table 2 and the internal gain characteristics are shown in Table 3.

Table 2: Glazing Performance Assumptions

Low Energy Cooling DOE2.1E Window Assumptions		
T24 California Climate Zone	**Window U-Value**	**Window RSHG**
1, 16	0.49	0.43
3 to 5	0.81	0.41
6 to 9	0.81	0.34
10 to 15	0.49	0.31

NOTE: Title-24 Overhang Factors (OF) provide an external shading correction to Solar Heat Gain Coefficient (SGHC) to produce the Relative Solar Heat Gain (RSHG) compliance rating. An OF equal to 1.0 means no overhangs, OF < 1.0 means overhangs are used. Details are located on page 3.38 of the 2001 Title 24 Nonresidential Manual.

Table 3: Internal Load Assumptions

Low Energy Cooling DOE2.1E Model Assumptions for: Basic T-24 Comply / Current Best Practice / Premium Energy Efficient			
Building Type	**Internal Gains**		
	Occupant Density (gross sf/person)	**Lighting Power Density,** W/sf (LPD using Title 24 Complete Building Method)	**Equip. Power Density,** W/sf (Whole Building EPD)
Design assumptions	390	1.2 / 1.0 / 0.8	2.50
Expected actual usage	390	1.2 / 1.0 / 0.8	1.0

Two levels of thermal mass were modeled, "Low Mass" and "High Mass". Low Mass is a typical office construction, with relatively few structural components being exposed to the space. Obstructions to heat transfer between the space and the structural concrete are drop ceiling panels, floor carpeting and wall furring behind the gypsum board. The High Mass construction assumes there are no ceiling plenums and the concrete floors are covered with a vinyl cladding. Since the systems modeled in this phase do not explicitly exploit thermal mass, the differences in performance between the Low Mass and High Mass construction results are relatively small.

System Sizing

The fans, cooling coil, chiller and cooling tower in the baseline system were sized for each climate zone using the autosizing facility in DOE-2. The combined efficiency of the fan, drive and motor was assumed to be 0.68. The maximum turndown for the VAV systems was taken to be 0.33 and the fans were assumed to have variable speed drives.

A key determinant of the benefit of low energy supplemental cooling systems is the trade-off between the reduction in the energy consumption of the conventional system and the parasitic losses associated with the low energy cooling system. Particularly important are the increases in fan energy consumption resulting from the pressure drops across any additional heat exchangers. The baseline system was assumed to have a pressure drop, under design conditions, of 3.5 inches of water on the supply side and 1 inch on the return. The direct evaporative cooling element was assumed to add 0.25 inches. The indirect evaporative cooling element was assumed to add 0.75 inches, both on the primary side and the secondary side. The effectivenesses of the direct and the indirect cooling elements were assumed to be 0.85 and 0.65, respectively.

Results

Baseline performance

Figure 5 shows a comparison of the energy use intensity of the baseline building in the Oakland climate zone to the distribution of actual energy use intensities for commercial office buildings in that climate zone, as contained in the California Energy Commission's California End Use Study (CEUS) database. The comparison was performed using the Cal-Arch on-line benchmarking tool (http://poet.lbl.gov/cal-arch/). One reason why the energy use intensity of the baseline is high is that it uses designers' assumptions about equipment loads (2.5 W/sf). As long as designers feel the need to make conservative (i.e. high) assumptions about equipment loads, these assumptions need to be included when producing design guidance, which is one of the aims of the part of the study reported here.

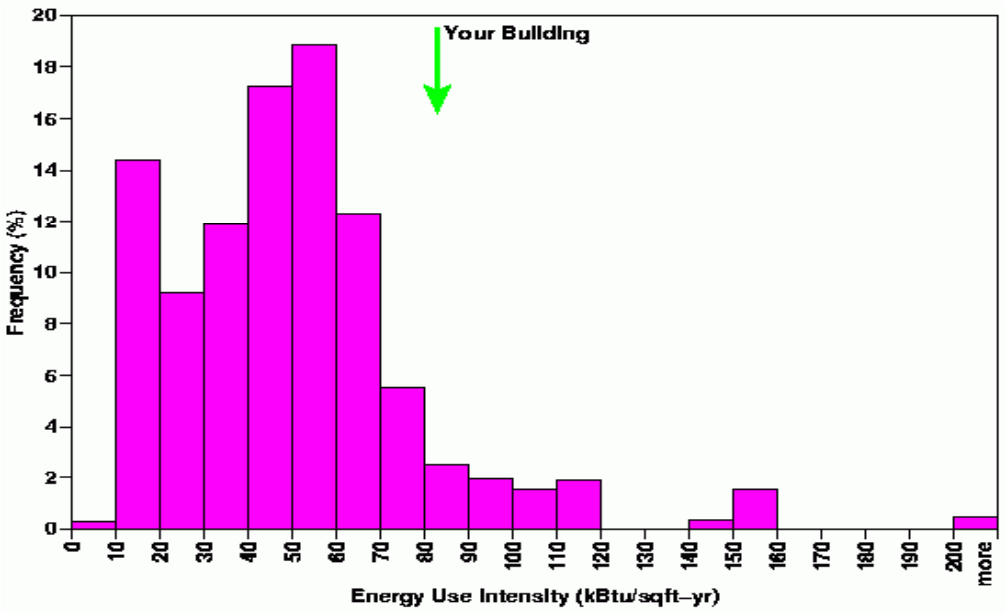

Figure 5: Cal-Arch benchmark of the Oakland prototype with 2.5W/sf EPD

The relative system performance using an equipment load that is more representative of real building operation (1.0 W/sf) was also examined. The Cal-Arch ranking of this model is displayed in Figure 6

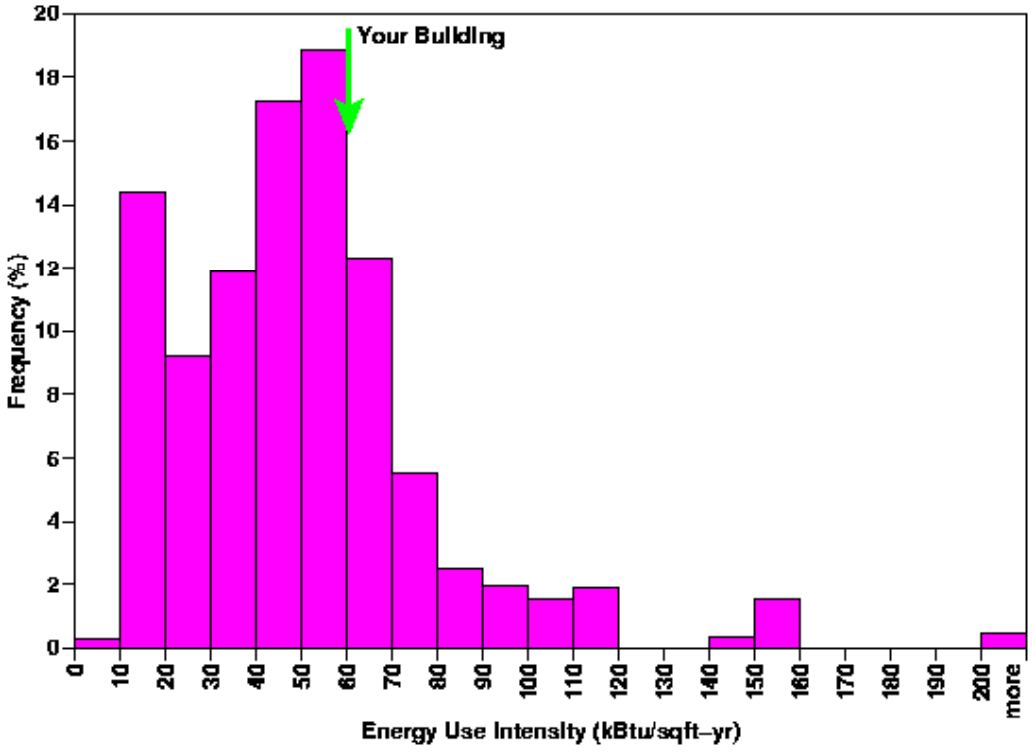

Figure 6: Cal-Arch benchmark of the Oakland prototype with 1.0 W/sf EPD

Results

Energy and peak demand comparisons

Table 4 shows the energy performance results for the different low energy cooling systems, relative to the unassisted conventional system ('Vapor Compression VAV'). Negative numbers indicate reduced energy consumption. The values for the reference conventional system are Energy Use Intensities (kWh/sf.yr). The results, which are discussed in more detail below, indicate substantial energy savings potential for displacement ventilation, particularly in conjunction with evaporative cooling.

Table 4: HVAC energy use intensity for different systems

System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-9.54%	-11.49%	-8.09%	-8.07%	-15.61%	-5.73%	4.36%	-3.56%
Evap. Pre-Cool, ind/direct on outside air	-18.95%	-22.46%	-22.50%	-23.70%	-29.64%	-21.17%	-11.94%	-17.99%
Displ. Vent., vapor compression	-61.60%	-29.82%	-57.32%	-46.98%	-49.84%	-38.82%	-44.02%	-39.47%
Displ. Vent., w/ CompAC + ind pre-cool	-56.57%	-50.79%	-65.28%	-61.41%	-64.19%	-56.52%	-60.43%	-56.62%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-55.01%	-60.73%	-67.85%	-68.58%	-67.89%	-67.73%	-67.86%	-65.40%
Cool Beam, vapor comp.	62.20%	13.22%	11.75%	7.82%	14.61%	-10.87%	-5.91%	-4.71%
Vapor Compression - VAV	**2.37**	**4.14**	**3.56**	**4.22**	**3.74**	**4.98**	**5.06**	**4.89**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-10.49%	-13.07%	-17.33%	-9.64%	-13.97%	-28.00%	-16.39%	-16.31%
Evap. Pre-Cool, ind/direct on outside air	-23.92%	-23.27%	-30.66%	-23.14%	-26.67%	-41.92%	-29.46%	-29.66%
Displ. Vent., vapor compression	-34.00%	-27.09%	-19.85%	-29.46%	-22.27%	-15.26%	-11.25%	-29.27%
Displ. Vent., w/ CompAC + ind pre-cool	-55.35%	-54.24%	-77.61%	-49.48%	-48.81%	-54.06%	-43.18%	-51.53%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-65.41%	-62.87%	-61.91%	-61.92%	-60.23%	-67.23%	-57.38%	-58.27%
Cool Beam, vapor comp.	-10.14%	-5.26%	6.54%	8.24%	4.43%	-0.71%	-13.82%	42.99%
Vapor Compression - VAV	**5.04**	**5.06**	**4.69**	**4.47**	**4.83**	**5.28**	**6.68**	**3.24**

Table 5 shows the corresponding peak electrical demand due to the HVAC system and Table 6 shows the annual load factor, defined as the ratio of the average electric load to the peak load. The average load is obtained by dividing the electric energy consumption for the year by the number of hours (8,760) in a year. A smaller load factor corresponds to a more unfavorable load shape from the utility perspective. A number of the low energy cooling systems have load factor values that are less than the corresponding values for the conventional system, indicating that the majority of the energy savings are obtained at part load conditions. The one exception is the cool beam system, where the load factor is higher than for the conventional system. The reduction in fan-power associated with using water to distribute cooling to the occupied spaces is greatest at times of peak load because of the assumed cube law dependence of fan power on flow rate in VAV systems with variable speed drives.

Table 5: HVAC peak power density results for different systems

System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	1.18	2.04	1.63	2.01	1.42	2.14	2.37	2.11
Evap. Pre-Cool, ind/direct on outside air	0.97	2.05	1.52	1.94	1.30	2.07	2.38	2.08
Displ. Vent., vapor compression	1.06	1.96	1.39	2.00	1.71	1.90	1.93	1.88
Displ. Vent., w/ CompAC + ind pre-cool	0.67	1.55	0.86	1.46	0.97	1.62	1.54	1.54
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.43	1.56	0.60	1.41	0.70	1.54	1.44	1.50
Cool Beam, vapor comp.	1.17	1.55	1.21	1.55	1.38	1.36	1.60	1.49
Vapor Compression - VAV	**1.58**	**2.05**	**1.71**	**2.04**	**1.72**	**2.04**	**2.07**	**2.01**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.17	2.10	2.09	2.21	2.14	1.82	2.49	1.77
Evap. Pre-Cool, ind/direct on outside air	2.22	2.23	2.06	2.16	2.11	1.74	2.54	1.70
Displ. Vent., vapor compression	2.06	2.02	2.37	2.07	2.11	2.18	2.36	2.07
Displ. Vent., w/ CompAC + ind pre-cool	1.74	1.51	0.43	1.75	1.65	1.44	2.12	1.28
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.68	1.74	1.58	1.66	1.62	1.22	2.09	1.12
Cool Beam, vapor comp.	1.39	1.45	1.68	1.64	1.65	1.55	1.67	1.48
Vapor Compression - VAV	**2.10**	**2.08**	**2.22**	**2.14**	**2.17**	**2.06**	**2.38**	**1.95**

Table 6: HVAC Load load factor results for different systems

System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.203	0.203	0.223	0.216	0.246	0.247	0.250	0.251
Evap. Pre-Cool, ind/direct on outside air	0.222	0.177	0.203	0.186	0.222	0.214	0.210	0.217
Displ. Vent., vapor compression	0.096	0.167	0.122	0.126	0.121	0.181	0.165	0.177
Displ. Vent., w/ CompAC + ind pre-cool	0.172	0.149	0.160	0.125	0.152	0.150	0.146	0.155
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.279	0.118	0.213	0.105	0.190	0.117	0.126	0.127
Cool Beam, vapor comp.	0.368	0.342	0.365	0.329	0.343	0.368	0.333	0.352
Vapor Compression - VAV	**0.171**	**0.231**	**0.237**	**0.236**	**0.248**	**0.279**	**0.279**	**0.278**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.234	0.237	0.210	0.207	0.221	0.237	0.255	0.171
Evap. Pre-Cool, ind/direct on outside air	0.195	0.197	0.178	0.180	0.190	0.200	0.211	0.150
Displ. Vent., vapor compression	0.182	0.207	0.180	0.172	0.202	0.233	0.286	0.124
Displ. Vent., w/ CompAC + ind pre-cool	0.146	0.173	0.279	0.146	0.170	0.191	0.204	0.137
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.117	0.122	0.128	0.116	0.134	0.161	0.155	0.135
Cool Beam, vapor comp.	0.366	0.373	0.336	0.333	0.346	0.383	0.394	0.349
Vapor Compression - VAV	**0.274**	**0.277**	**0.242**	**0.239**	**0.255**	**0.293**	**0.321**	**0.190**

Results for the parametric variations described above are given in the Appendices. Comparison of the results for equipment heat gains of 2.5 W/sf and 1.0 W/sf shows that the percentage savings for the different low energy cooling systems are almost independent of heat gain level, the lower gain level resulting in slightly greater percentage savings but slightly lower absolute savings.

Discussion

Methods of space conditioning

The way in which the space is conditioned can have a significant effect on performance. Figure 7 compares the energy performance in four selected climate zones of three different space conditioning methods in a building with 12 hr/day occupancy and an economizer, such as an office building. System 1 is a conventional mixing ventilation VAV system, System 2 is a cooled beam system in which the ventilation system supplies only the minimum amount of outside air required by the occupants, System 3 is a displacement ventilation VAV system with a supply air temperature of 65^{o}F and System 4 is an underfloor air distribution system with a supply air temperature of 60^{o}F, half way between the supply air temperatures of the mixing ventilation and the 'true' displacement ventilation systems.

The cooled beam system has slightly higher energy consumption than the mixing ventilation system in the Northern California climates, where the loss of free cooling associated with a minimum outside air system outweighs the reduction in fan energy. In the Southern California climates, the reduction in fan energy is the dominant effect. Since the temperature of the water supplied to cool beams is typically ~59^{o}F, one obvious option is to use cooling tower water directly, without the use of a chiller. Preliminary simulation results, not presented here, indicate that the cooling tower needs to be sized for a closer approach to the wet bulb temperature than is conventional practice for chilled water plants if significant benefits from water-side free cooling are to be obtained.

In all four climates, the displacement ventilation system consumes significantly less energy than the mixing ventilation system, mainly because the higher supply air temperature allows significantly greater use of free cooling, particularly in the relatively mild Oakland climate. The fan energy is slightly less because of the lower pressure drop associated with the under-floor distribution system. The magnitudes of the savings associated with displacement ventilation should be treated with caution pending the availability of a more detailed model of displacement ventilation that is currently being implemented in the Department of Energy's EnergyPlus program (Crawley et al. 2000). The quasi-displacement ventilation underfloor air distribution system has savings that are slightly less half those of the true displacement ventilation system in Oakland and significantly less in the other climates. Inspection of the results for all 16 climates in the Appendices shows that the underfloor air distribution system has savings that are ~half those of the true displacement ventilation system in the milder climates and significantly less than half in the more severe climates. This behavior is as expected, since the savings are the result of increased use of free cooling made possible by the higher supply air temperature.

Figure 8 is the corresponding plot to Figure 7 for a full outside air system, such as would be used in a laboratory building. In this case, the advantage of the displacement ventilation and underfloor systems is even more pronounced since the ventilation load is greater. The calculation of the energy consumption of the cooled beam system assumes that the ventilation rate is the minimum outside airflow rate, i.e. that the requirement is for no recirculation rather than for a high outside airflow rate. The energy consumption is then less than that of the mixing ventilation system in all climates. If a high ventilation rate is required, the performance will be similar to that of the mixing ventilation system and the ventilation air, rather than the cooled beam, will meet the majority of the cooling load. The conclusion is that cooled beams are beneficial if the climate is such that there are only modest savings to be gained from free cooling and/or the use of a water-based system allows the reduction of the ventilation rate and hence the ventilation load.

Results for all 16 climates are presented in the Appendices.

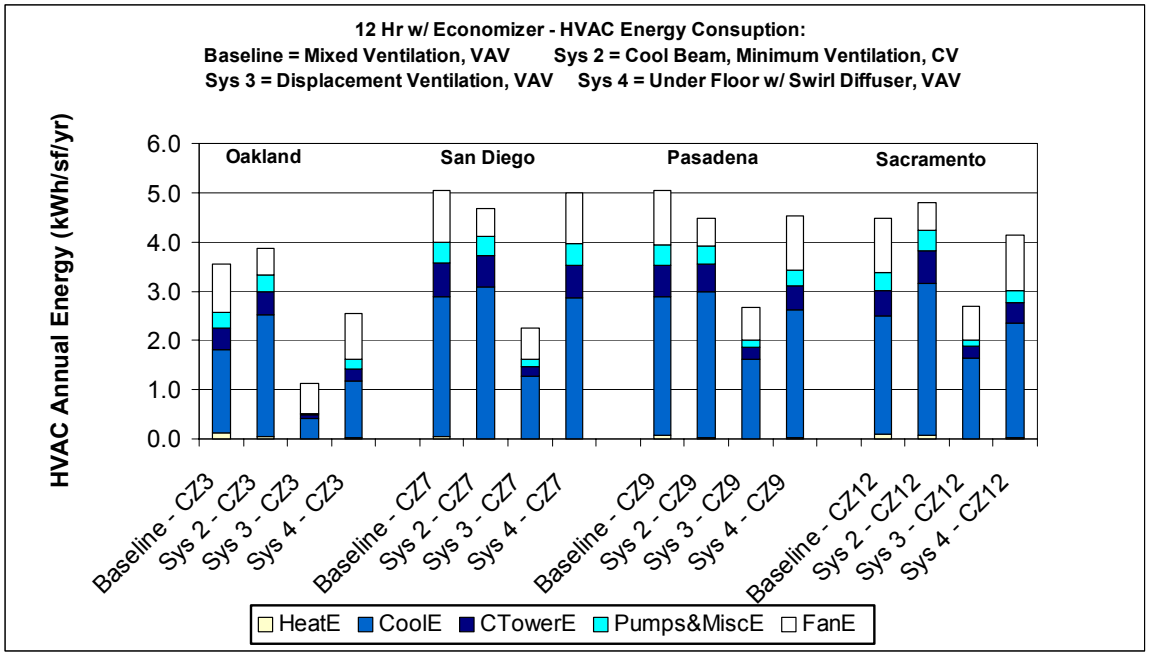

Figure 7: Energy performance of different space conditioning methods for buildings with an economizer and 12 hr/day occupancy

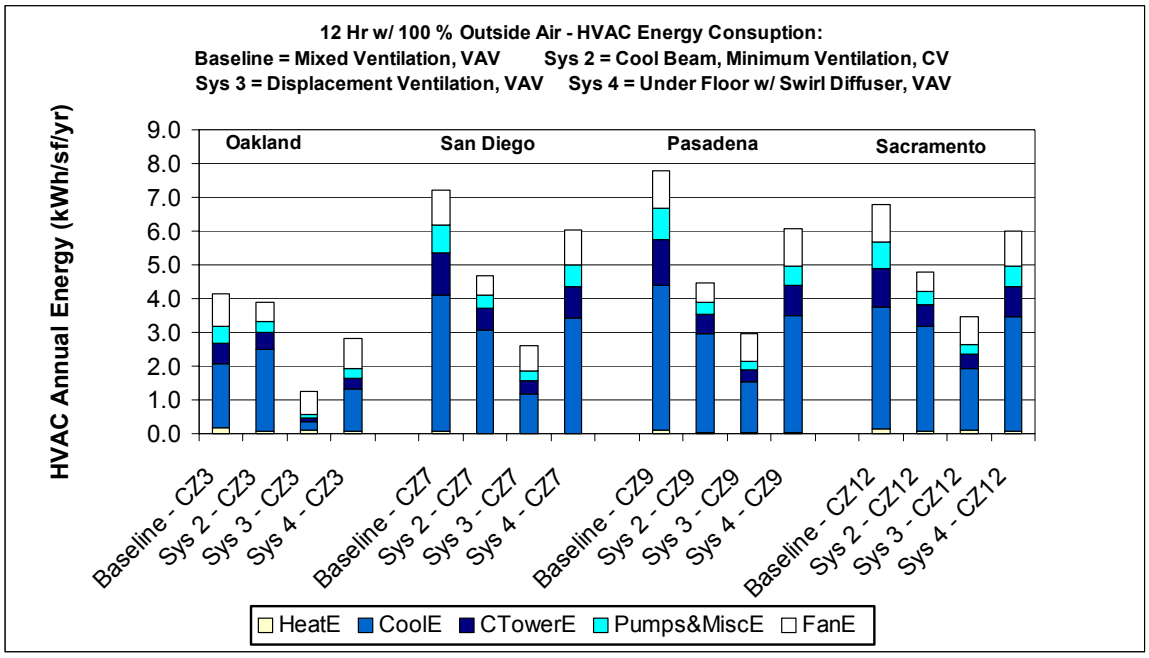

Figure 8: Energy performance of different space conditioning methods for 100% outside air systems and 12 hr/day occupancy

Evaporative Pre-cooling

Figure 9 shows the benefits of evaporative pre-cooling for mixing ventilation HVAC systems in the four selected climates. System 1 is a conventional mixing ventilation VAV system, System 2 has an indirect evaporative cooling stage before the cooling coil and System 3 has an indirect evaporative cooling stage followed by a direct cooling stage before the cooling coil. The evaporative pre-cooling provides only modest improvements. In San Diego (CZ 7), the indirect stage provides negligible benefit. In the other climates, the benefit is partially offset by the significant increase in fan power resulting from the 0.75 in H_2O pressure drop at design flow caused by the heat exchanger for the indirect stage. The addition of a direct stage produces significant additional savings but results in increased humidity in the space that is problematical in San Diego (116 hrs/yr above 70% RH) and has a minor impact in other climates. Results for all 16 climates are presented in the Appendices.

Figure 10 is the corresponding plot to Figure 9 for displacement ventilation rather than mixing ventilation. In Oakland (CZ 3), the benefit of evaporative cooling is relatively small because the chiller use in the unassisted displacement ventilation system is quite small, so that the chiller savings do not significantly exceed the increase in fan energy. In the other climates, the chiller use, and hence the potential savings, are much greater. The approximate method of modeling displacement ventilation used here does not facilitate the estimation of the humidity in the space; however, the use of direct evaporative cooling with relatively high supply air temperatures can be expected to produce high relative humidities in the lower regions of the occupied space and is not recommended without more detailed psychrometric calculations. In spite of this restriction to indirect evaporative cooling, the combination of evaporative cooling and displacement ventilation produces very significant reductions in energy consumption, and also in peak demand. The indirect systems were modeled in two configurations, either using outside air or return air on the wet side of the media. In every case studied, the use of outside air resulted in better performance.

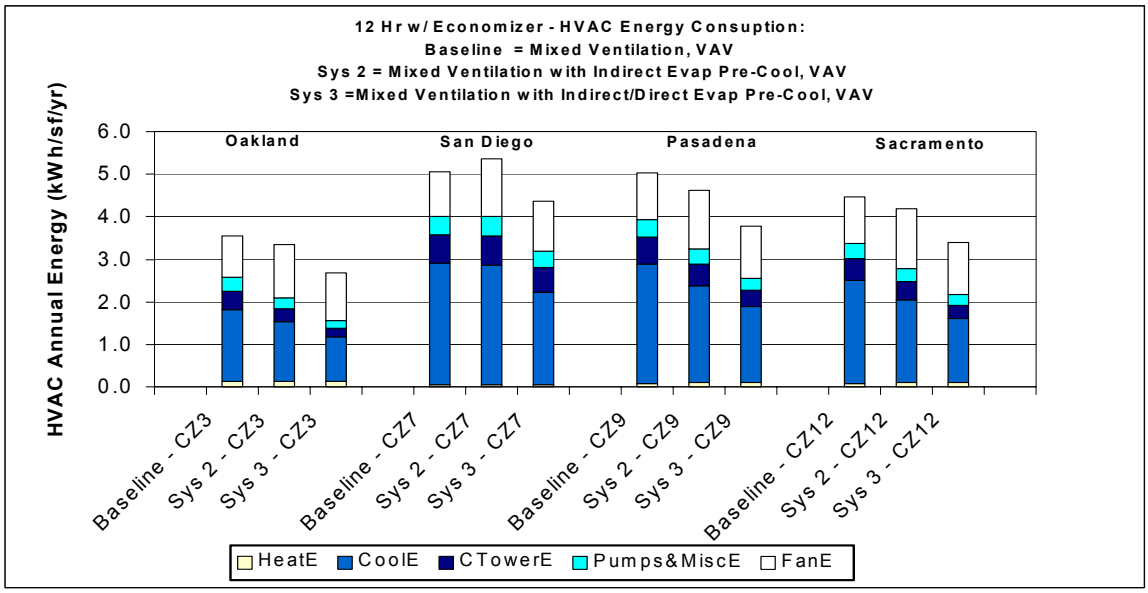

Figure 9: Evaporative pre-cooling for mixing ventilation

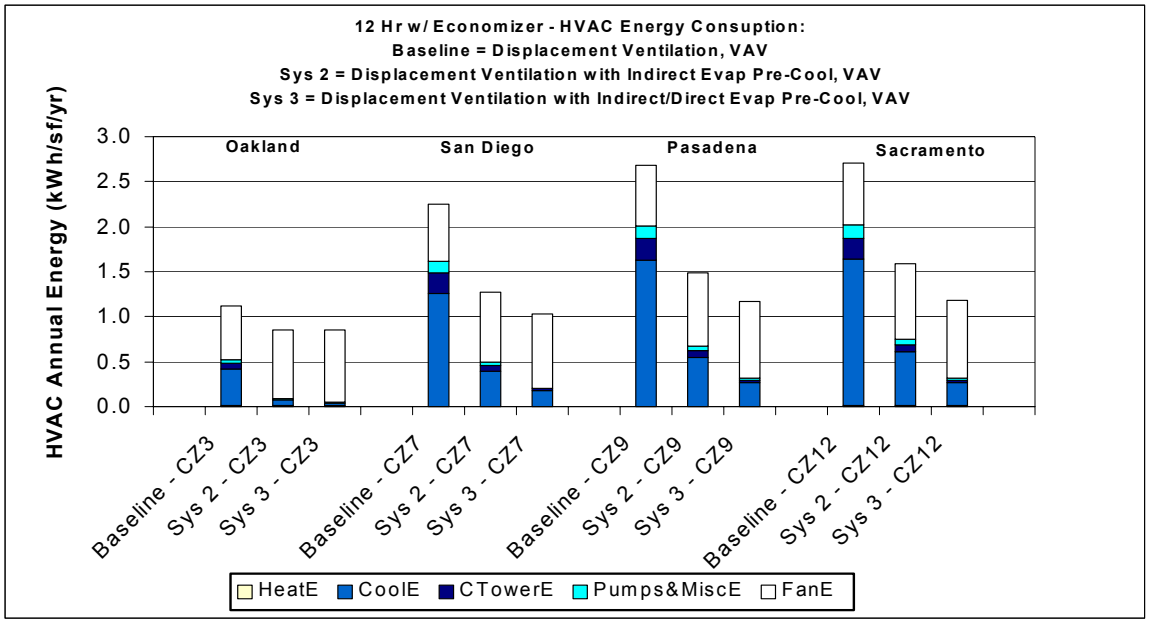

Figure 10: Evaporative pre-cooling for displacement ventilation

Figure 11 shows the progressive reduction in energy use intensity (EUI) and peak demand of changing from conventional mixing ventilation (upper right of each graph) to displacement ventilation and then adding indirect evaporative pre-cooling. Buildings that need 100% outside air and/or operate 24 hours/day have the largest savings potential in absolute terms. In each case, the fractional reduction in EUI is greater than the fractional reduction in peak demand, although laboratories and other buildings that need 100% outside air and operate ~12 hours/day show only a slight degradation in load factor. The negligible reduction in peak demand on changing from mixing ventilation to displacement ventilation in buildings, such as offices and retail stores, that have economizers is because the ambient dry bulb temperature is greater than the return temperature from displacement ventilation (~85^{o}F) so there is no free cooling. The exception is Oakland, where the ambient dry bulb is 84^{o}F at the time of the peak load.

The addition of indirect evaporative pre-cooling improves the load factor because there is significant potential for evaporative cooling at the time of the peak demand, which tends to occur when the ambient dry bulb temperature is high but the ambient wet bulb temperature is not especially high. The potential for useful evaporative pre-cooling tends to be lower at times when the load is lower because of the availability of conventional free cooling. For displacement ventilation, at least, this somewhat contradicts the conventional wisdom that evaporative cooling has a deleterious effect on load factor.

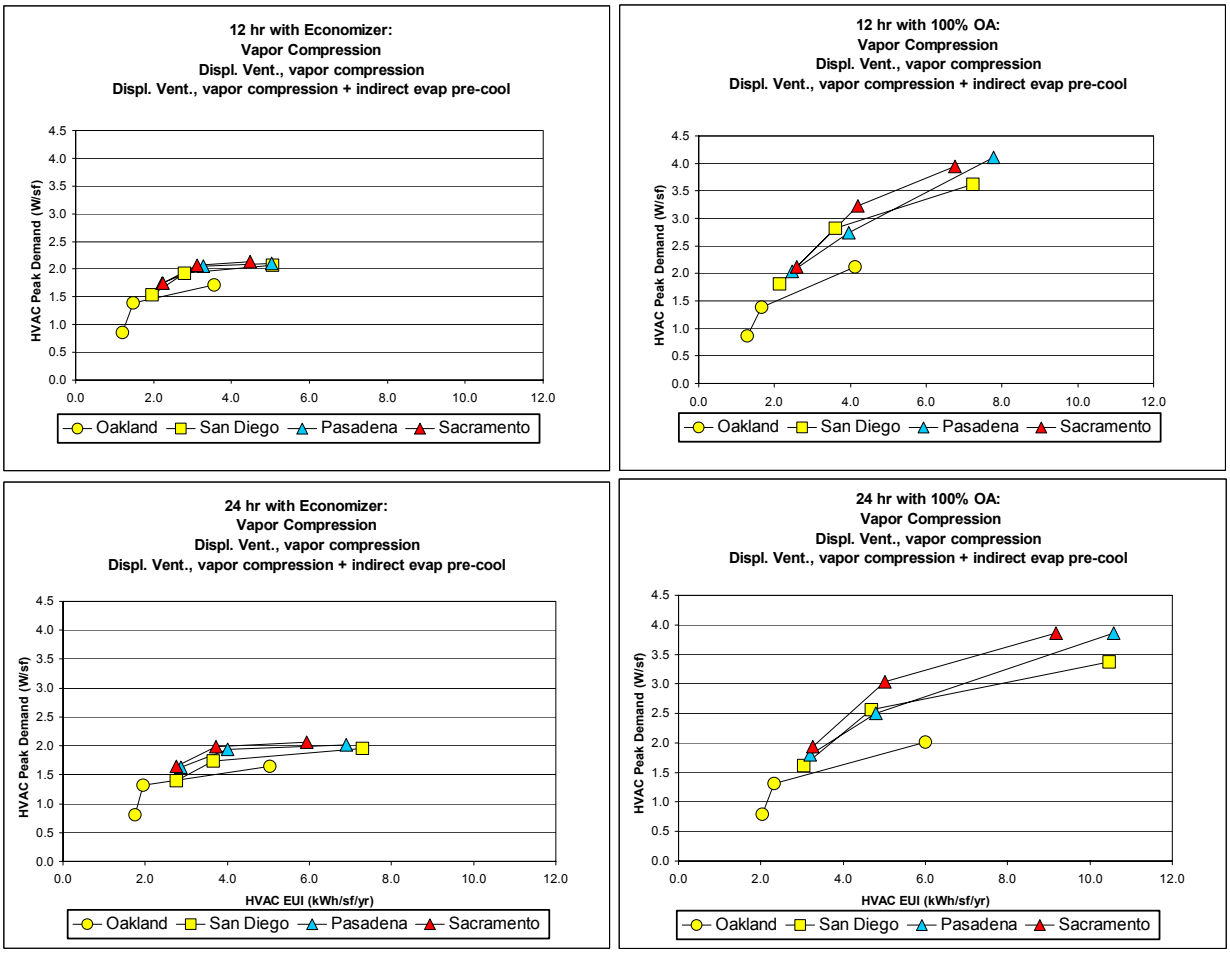

Figure 11: Effect of system selection on peak demand and energy consumption for the four modeled occupancy/ventilation regimes

Conclusions

The way in which spaces are cooled has a significant effect on energy performance. In particular, displacement ventilation systems are able to make significantly greater use of free cooling and evaporative cooling because of their higher supply air temperature. This is apparent in all climates and is particularly so in less severe climates. The quantitative estimates of savings should be treated with caution pending the availability of a validated model of the operation of spaces with displacement ventilation in a whole building simulation program

Evaporative pre-cooling is beneficial in all California climates. The benefits are greater in the less humid regions but are still significant on the coast. Evaporative cooling complements displacement ventilation in all climates, although the benefits in the cooler Northern coastal climates are mainly in peak load reduction.

Fan energy consumption is a key component of system performance. The benefits of evaporative cooling systems are reduced by the additional fan power needed to overcome the increased air-side pressure, in the case of air-side evaporative cooling, or to operate the cooling tower in the case of the water-side economizer.

Peak demand can be reduced by improving distribution system efficiency. Cool beam systems perform better than conventional systems at times of peak load because of the reduced fan-power associated with using water to distribute cooling to the occupied spaces.

Peak demand could be reduced by making use of thermal storage. In particular, low energy cooling systems that store daytime heat gains in the fabric of the building and then dissipate heat directly to the environment at night have the potential to reduce peak demand substantially. These systems will be studied in a follow-on project using the models currently being developed for EnergyPlus.

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Appendix A
Results for 12 Hour Occupancy with Economizer

Typical Design Equipment Power Density (2.5 W/sf)

Displacement Ventilation Supply Air Temperature: 65°F

12Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-9.54%	-11.49%	-8.09%	-8.07%	-15.61%	-5.73%	4.36%	-3.56%
Evap. Pre-Cool, ind/direct on outside air	-18.95%	-22.46%	-22.50%	-23.70%	-29.64%	-21.17%	-11.94%	-17.99%
Displ. Vent., vapor compression	-61.60%	-29.82%	-57.32%	-46.98%	-49.84%	-38.82%	-44.02%	-39.47%
Displ. Vent., w/ CompAC + ind pre-cool	-56.57%	-50.79%	-65.28%	-61.41%	-64.19%	-56.52%	-60.43%	-56.62%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-55.01%	-60.73%	-67.85%	-68.58%	-67.89%	-67.73%	-67.86%	-65.40%
Cool Beam, vapor comp.	62.20%	13.22%	11.75%	7.82%	14.61%	-10.87%	-5.91%	-4.71%
Vapor Compression - VAV	**2.37**	**4.14**	**3.56**	**4.22**	**3.74**	**4.98**	**5.06**	**4.89**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-10.49%	-13.07%	-17.33%	-9.64%	-13.97%	-28.00%	-16.39%	-16.31%
Evap. Pre-Cool, ind/direct on outside air	-23.92%	-23.27%	-30.66%	-23.14%	-26.67%	-41.92%	-29.46%	-29.66%
Displ. Vent., vapor compression	-34.00%	-27.09%	-19.85%	-29.46%	-22.27%	-15.26%	-11.25%	-29.27%
Displ. Vent., w/ CompAC + ind pre-cool	-55.35%	-54.24%	-77.61%	-49.48%	-48.81%	-54.06%	-43.18%	-51.53%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-65.41%	-62.87%	-61.91%	-61.92%	-60.23%	-67.23%	-57.38%	-58.27%
Cool Beam, vapor comp.	-10.14%	-5.26%	6.54%	8.24%	4.43%	-0.71%	-13.82%	42.99%
Vapor Compression - VAV	**5.04**	**5.06**	**4.69**	**4.47**	**4.83**	**5.28**	**6.68**	**3.24**

12Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 65o F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	1.18	2.04	1.63	2.01	1.42	2.14	2.37	2.11
Evap. Pre-Cool, ind/direct on outside air	0.97	2.05	1.52	1.94	1.30	2.07	2.38	2.08
Displ. Vent., vapor compression	1.06	1.96	1.39	2.00	1.71	1.90	1.93	1.88
Displ. Vent., w/ CompAC + ind pre-cool	0.67	1.55	0.86	1.46	0.97	1.62	1.54	1.54
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.43	1.56	0.60	1.41	0.70	1.54	1.44	1.50
Cool Beam, vapor comp.	1.17	1.55	1.21	1.55	1.38	1.36	1.60	1.49
Vapor Compression - VAV	**1.58**	**2.05**	**1.71**	**2.04**	**1.72**	**2.04**	**2.07**	**2.01**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.17	2.10	2.09	2.21	2.14	1.82	2.49	1.77
Evap. Pre-Cool, ind/direct on outside air	2.22	2.23	2.06	2.16	2.11	1.74	2.54	1.70
Displ. Vent., vapor compression	2.06	2.02	2.37	2.07	2.11	2.18	2.36	2.07
Displ. Vent., w/ CompAC + ind pre-cool	1.74	1.51	0.43	1.75	1.65	1.44	2.12	1.28
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.68	1.74	1.58	1.66	1.62	1.22	2.09	1.12
Cool Beam, vapor comp.	1.39	1.45	1.68	1.64	1.65	1.55	1.67	1.48
Vapor Compression - VAV	**2.10**	**2.08**	**2.22**	**2.14**	**2.17**	**2.06**	**2.38**	**1.95**

12Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 65o F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.203	0.203	0.223	0.216	0.246	0.247	0.250	0.251
Evap. Pre-Cool, ind/direct on outside air	0.222	0.177	0.203	0.186	0.222	0.214	0.210	0.217
Displ. Vent., vapor compression	0.096	0.167	0.122	0.126	0.121	0.181	0.165	0.177
Displ. Vent., w/ CompAC + ind pre-cool	0.172	0.149	0.160	0.125	0.152	0.150	0.146	0.155
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.279	0.118	0.213	0.105	0.190	0.117	0.126	0.127
Cool Beam, vapor comp.	0.368	0.342	0.365	0.329	0.343	0.368	0.333	0.352
Vapor Compression - VAV	**0.171**	**0.231**	**0.237**	**0.236**	**0.248**	**0.279**	**0.279**	**0.278**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.234	0.237	0.210	0.207	0.221	0.237	0.255	0.171
Evap. Pre-Cool, ind/direct on outside air	0.195	0.197	0.178	0.180	0.190	0.200	0.211	0.150
Displ. Vent., vapor compression	0.182	0.207	0.180	0.172	0.202	0.233	0.286	0.124
Displ. Vent., w/ CompAC + ind pre-cool	0.146	0.173	0.279	0.146	0.170	0.191	0.204	0.137
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.117	0.122	0.128	0.116	0.134	0.161	0.155	0.135
Cool Beam, vapor comp.	0.366	0.373	0.336	0.333	0.346	0.383	0.394	0.349
Vapor Compression - VAV	**0.274**	**0.277**	**0.242**	**0.239**	**0.255**	**0.293**	**0.321**	**0.190**

Displacement Ventilation Supply Air Temperature: 60°F

12Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-9.54%	-11.49%	-8.09%	-8.07%	-15.61%	-5.73%	4.36%	-3.56%
Evap. Pre-Cool, ind/direct on outside air	-18.95%	-22.46%	-22.50%	-23.70%	-29.64%	-21.17%	-11.94%	-17.99%
Displ. Vent., vapor compression	-39.46%	-7.00%	-26.52%	-19.06%	-21.74%	-5.54%	0.52%	-8.91%
Displ. Vent., w/ CompAC + ind pre-cool	-43.97%	-27.63%	-39.66%	-35.14%	-43.90%	-24.33%	-20.28%	-27.68%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-46.92%	-39.68%	-53.17%	-48.38%	-56.64%	-42.82%	-40.00%	-41.27%
Cool Beam, vapor comp.	62.20%	13.22%	11.75%	7.82%	14.61%	-10.87%	-5.91%	-4.71%
Vapor Compression - VAV	**2.37**	**4.14**	**3.56**	**4.22**	**3.74**	**4.98**	**5.06**	**4.89**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-10.49%	-13.07%	-17.33%	-9.64%	-13.97%	-28.00%	-16.39%	-16.31%
Evap. Pre-Cool, ind/direct on outside air	-23.92%	-23.27%	-30.66%	-23.14%	-26.67%	-41.92%	-29.46%	-29.66%
Displ. Vent., vapor compression	-9.07%	-0.33%	-0.05%	-6.47%	-1.32%	3.75%	20.99%	-8.73%
Displ. Vent., w/ CompAC + ind pre-cool	-31.32%	-23.72%	-73.59%	-24.90%	-25.69%	-34.98%	-21.17%	-31.98%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-42.95%	-37.48%	-44.03%	-39.95%	-39.38%	-50.73%	-35.45%	-45.04%
Cool Beam, vapor comp.	-10.14%	-5.26%	6.54%	8.24%	4.43%	-0.71%	-13.82%	42.99%
Vapor Compression - VAV	**5.04**	**5.06**	**4.69**	**4.47**	**4.83**	**5.28**	**6.68**	**3.24**

12Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	1.18	2.04	1.63	2.01	1.42	2.14	2.37	2.11
Evap. Pre-Cool, ind/direct on outside air	0.97	2.05	1.52	1.94	1.30	2.07	2.38	2.08
Displ. Vent., vapor compression	1.48	2.29	1.83	2.30	2.01	2.36	2.70	2.24
Displ. Vent., w/ CompAC + ind pre-cool	1.10	2.10	1.61	2.04	1.45	2.22	2.61	2.10
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.76	2.21	1.38	2.02	1.25	2.17	2.49	2.12
Cool Beam, vapor comp.	1.17	1.55	1.21	1.55	1.38	1.36	1.60	1.49
Vapor Compression - VAV	**1.58**	**2.05**	**1.71**	**2.04**	**1.72**	**2.04**	**2.07**	**2.01**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.17	2.10	2.09	2.21	2.14	1.82	2.49	1.77
Evap. Pre-Cool, ind/direct on outside air	2.22	2.23	2.06	2.16	2.11	1.74	2.54	1.70
Displ. Vent., vapor compression	2.35	2.35	2.63	2.41	2.47	2.45	3.47	2.32
Displ. Vent., w/ CompAC + ind pre-cool	2.23	2.31	0.76	2.30	2.23	1.93	2.66	1.81
Displ. Vent., w/ CompAC + ind/dir pre-cool	2.35	2.44	2.20	2.28	2.25	1.83	2.87	1.75
Cool Beam, vapor comp.	1.39	1.45	1.68	1.64	1.65	1.55	1.67	1.48
Vapor Compression - VAV	**2.10**	**2.08**	**2.22**	**2.14**	**2.17**	**2.06**	**2.38**	**1.95**

12Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.203	0.203	0.223	0.216	0.246	0.247	0.250	0.251
Evap. Pre-Cool, ind/direct on outside air	0.222	0.177	0.203	0.186	0.222	0.214	0.210	0.217
Displ. Vent., vapor compression	0.108	0.190	0.160	0.167	0.161	0.225	0.212	0.224
Displ. Vent., w/ CompAC + ind pre-cool	0.135	0.161	0.148	0.150	0.160	0.191	0.173	0.189
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.185	0.128	0.134	0.121	0.143	0.148	0.136	0.152
Cool Beam, vapor comp.	0.368	0.342	0.365	0.329	0.343	0.368	0.333	0.352
Vapor Compression - VAV	**0.171**	**0.231**	**0.237**	**0.236**	**0.248**	**0.279**	**0.279**	**0.278**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.234	0.237	0.210	0.207	0.221	0.237	0.255	0.171
Evap. Pre-Cool, ind/direct on outside air	0.195	0.197	0.178	0.180	0.190	0.200	0.211	0.150
Displ. Vent., vapor compression	0.220	0.243	0.201	0.196	0.219	0.253	0.265	0.142
Displ. Vent., w/ CompAC + ind pre-cool	0.175	0.189	0.185	0.165	0.183	0.202	0.226	0.136
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.138	0.146	0.135	0.133	0.148	0.162	0.171	0.114
Cool Beam, vapor comp.	0.366	0.373	0.336	0.333	0.346	0.383	0.394	0.349
Vapor Compression - VAV	**0.274**	**0.277**	**0.242**	**0.239**	**0.255**	**0.293**	**0.321**	**0.190**

Typical Operating Equipment Power Density (1.0 W/sf)

Displacement Ventilation Supply Air Temperature: 65°F

12Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-4.59%	-11.41%	-7.87%	-10.50%	-14.16%	-7.06%	-5.20%	-6.94%
Evap. Pre-Cool, ind/direct on outside air	-13.02%	-22.74%	-21.67%	-23.32%	-28.66%	-21.58%	-20.40%	-20.66%
Displ. Vent., vapor compression	-62.21%	-32.84%	-59.51%	-48.60%	-51.80%	-41.22%	-47.83%	-41.84%
Displ. Vent., w/ CompAC + ind pre-cool	-57.72%	-54.01%	-66.99%	-63.66%	-65.95%	-58.74%	-64.58%	-59.27%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-56.28%	-64.10%	-69.24%	-70.51%	-69.37%	-69.94%	-71.65%	-67.74%
Cool Beam, vapor comp.	59.77%	14.28%	9.64%	8.84%	13.55%	-10.35%	-6.34%	-7.53%
Vapor Compression - VAV	**1.72**	**3.06**	**2.62**	**3.16**	**2.83**	**3.66**	**3.81**	**3.59**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-10.90%	-15.50%	-17.97%	-9.56%	-13.85%	-28.26%	-17.05%	-14.63%
Evap. Pre-Cool, ind/direct on outside air	-23.93%	-24.99%	-32.15%	-23.40%	-27.40%	-43.99%	-31.33%	-28.39%
Displ. Vent., vapor compression	-38.86%	-29.52%	-21.71%	-32.40%	-25.28%	-17.91%	-16.48%	-29.54%
Displ. Vent., w/ CompAC + ind pre-cool	-59.10%	-56.40%	-79.65%	-52.60%	-51.87%	-56.38%	-48.71%	-51.79%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-68.07%	-66.27%	-65.28%	-64.88%	-63.88%	-70.86%	-62.82%	-58.60%
Cool Beam, vapor comp.	-10.69%	-2.44%	6.68%	6.49%	6.23%	0.35%	-12.45%	41.21%
Vapor Compression - VAV	**3.77**	**3.70**	**3.57**	**3.34**	**3.63**	**4.02**	**5.11**	**2.48**

12Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	0.91	1.60	1.23	1.58	1.11	1.68	1.67	1.62
Evap. Pre-Cool, ind/direct on outside air	0.81	1.58	1.18	1.54	0.98	1.63	1.66	1.59
Displ. Vent., vapor compression	0.79	1.51	1.01	1.54	1.28	1.42	1.49	1.45
Displ. Vent., w/ CompAC + ind pre-cool	0.53	1.17	0.65	1.12	0.74	1.23	1.18	1.16
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.37	1.15	0.47	1.06	0.49	1.15	1.07	1.13
Cool Beam, vapor comp.	0.97	1.31	1.02	1.35	1.20	1.15	1.40	1.17
Vapor Compression - VAV	**1.13**	**1.64**	**1.34**	**1.67**	**1.38**	**1.63**	**1.69**	**1.61**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	1.73	1.63	1.67	1.75	1.73	1.47	2.03	1.41
Evap. Pre-Cool, ind/direct on outside air	1.74	1.72	1.64	1.70	1.69	1.39	2.06	1.34
Displ. Vent., vapor compression	1.49	1.55	1.92	1.60	1.66	1.76	1.89	1.64
Displ. Vent., w/ CompAC + ind pre-cool	1.24	1.18	0.37	1.34	1.29	1.15	1.62	1.03
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.26	1.25	1.20	1.25	1.24	0.91	1.59	0.83
Cool Beam, vapor comp.	1.20	1.26	1.48	1.35	1.44	1.36	1.46	1.29
Vapor Compression - VAV	**1.70**	**1.67**	**1.85**	**1.73**	**1.79**	**1.70**	**1.98**	**1.59**

12Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.196	0.190	0.216	0.199	0.238	0.226	0.245	0.229
Evap. Pre-Cool, ind/direct on outside air	0.200	0.167	0.192	0.174	0.224	0.197	0.207	0.198
Displ. Vent., vapor compression	0.089	0.153	0.116	0.117	0.115	0.168	0.151	0.160
Displ. Vent., w/ CompAC + ind pre-cool	0.150	0.135	0.147	0.113	0.142	0.136	0.130	0.139
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.223	0.107	0.189	0.097	0.192	0.106	0.114	0.114
Cool Beam, vapor comp.	0.307	0.299	0.310	0.282	0.291	0.319	0.287	0.316
Vapor Compression - VAV	**0.174**	**0.213**	**0.223**	**0.217**	**0.234**	**0.255**	**0.257**	**0.254**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.218	0.216	0.197	0.193	0.204	0.221	0.238	0.167
Evap. Pre-Cool, ind/direct on outside air	0.184	0.181	0.167	0.168	0.175	0.183	0.194	0.147
Displ. Vent., vapor compression	0.173	0.189	0.163	0.158	0.184	0.212	0.258	0.118
Displ. Vent., w/ CompAC + ind pre-cool	0.139	0.153	0.223	0.133	0.152	0.172	0.185	0.129
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.107	0.112	0.116	0.105	0.119	0.145	0.137	0.137
Cool Beam, vapor comp.	0.315	0.323	0.289	0.295	0.301	0.335	0.349	0.302
Vapor Compression - VAV	**0.253**	**0.253**	**0.220**	**0.220**	**0.232**	**0.270**	**0.294**	**0.178**

Displacement Ventilation Supply Air Temperature: 60°F

12Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-4.59%	-11.41%	-7.87%	-10.50%	-14.16%	-7.06%	-5.20%	-6.94%
Evap. Pre-Cool, ind/direct on outside air	-13.02%	-22.74%	-21.67%	-23.32%	-28.66%	-21.58%	-20.40%	-20.66%
Displ. Vent., vapor compression	-62.21%	-32.84%	-59.51%	-48.60%	-51.80%	-41.22%	-47.83%	-41.84%
Displ. Vent., w/ CompAC + ind pre-cool	-57.72%	-54.01%	-66.99%	-63.66%	-65.95%	-58.74%	-64.58%	-59.27%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-56.28%	-64.10%	-69.24%	-70.51%	-69.37%	-69.94%	-71.65%	-67.74%
Cool Beam, vapor comp.	59.77%	14.28%	9.64%	8.84%	13.55%	-10.35%	-6.34%	-7.53%
Vapor Compression - VAV	**1.72**	**3.06**	**2.62**	**3.16**	**2.83**	**3.66**	**3.81**	**3.59**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-10.90%	-15.50%	-17.97%	-9.56%	-13.85%	-28.26%	-17.05%	-14.63%
Evap. Pre-Cool, ind/direct on outside air	-23.93%	-24.99%	-32.15%	-23.40%	-27.40%	-43.99%	-31.33%	-28.39%
Displ. Vent., vapor compression	-38.86%	-29.52%	-21.71%	-32.40%	-25.28%	-17.91%	-16.48%	-29.54%
Displ. Vent., w/ CompAC + ind pre-cool	-59.10%	-56.40%	-79.65%	-52.60%	-51.87%	-56.38%	-48.71%	-51.79%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-68.07%	-66.27%	-65.28%	-64.88%	-63.88%	-70.86%	-62.82%	-58.60%
Cool Beam, vapor comp.	-10.69%	-2.44%	6.68%	6.49%	6.23%	0.35%	-12.45%	41.21%
Vapor Compression - VAV	**3.77**	**3.70**	**3.57**	**3.34**	**3.63**	**4.02**	**5.11**	**2.48**

12Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	0.91	1.60	1.23	1.58	1.11	1.68	1.67	1.62
Evap. Pre-Cool, ind/direct on outside air	0.81	1.58	1.18	1.54	0.98	1.63	1.66	1.59
Displ. Vent., vapor compression	0.79	1.51	1.01	1.54	1.28	1.42	1.49	1.45
Displ. Vent., w/ CompAC + ind pre-cool	0.53	1.17	0.65	1.12	0.74	1.23	1.18	1.16
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.37	1.15	0.47	1.06	0.49	1.15	1.07	1.13
Cool Beam, vapor comp.	0.97	1.31	1.02	1.35	1.20	1.15	1.40	1.17
Vapor Compression - VAV	**1.13**	**1.64**	**1.34**	**1.67**	**1.38**	**1.63**	**1.69**	**1.61**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	1.73	1.63	1.67	1.75	1.73	1.47	2.03	1.41
Evap. Pre-Cool, ind/direct on outside air	1.74	1.72	1.64	1.70	1.69	1.39	2.06	1.34
Displ. Vent., vapor compression	1.49	1.55	1.92	1.60	1.66	1.76	1.89	1.64
Displ. Vent., w/ CompAC + ind pre-cool	1.24	1.18	0.37	1.34	1.29	1.15	1.62	1.03
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.26	1.25	1.20	1.25	1.24	0.91	1.59	0.83
Cool Beam, vapor comp.	1.20	1.26	1.48	1.35	1.44	1.36	1.46	1.29
Vapor Compression - VAV	**1.70**	**1.67**	**1.85**	**1.73**	**1.79**	**1.70**	**1.98**	**1.59**

12Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.196	0.190	0.216	0.199	0.238	0.226	0.245	0.229
Evap. Pre-Cool, ind/direct on outside air	0.200	0.167	0.192	0.174	0.224	0.197	0.207	0.198
Displ. Vent., vapor compression	0.089	0.153	0.116	0.117	0.115	0.168	0.151	0.160
Displ. Vent., w/ CompAC + ind pre-cool	0.150	0.135	0.147	0.113	0.142	0.136	0.130	0.139
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.223	0.107	0.189	0.097	0.192	0.106	0.114	0.114
Cool Beam, vapor comp.	0.307	0.299	0.310	0.282	0.291	0.319	0.287	0.316
Vapor Compression - VAV	**0.174**	**0.213**	**0.223**	**0.217**	**0.234**	**0.255**	**0.257**	**0.254**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.218	0.216	0.197	0.193	0.204	0.221	0.238	0.167
Evap. Pre-Cool, ind/direct on outside air	0.184	0.181	0.167	0.168	0.175	0.183	0.194	0.147
Displ. Vent., vapor compression	0.173	0.189	0.163	0.158	0.184	0.212	0.258	0.118
Displ. Vent., w/ CompAC + ind pre-cool	0.139	0.153	0.223	0.133	0.152	0.172	0.185	0.129
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.107	0.112	0.116	0.105	0.119	0.145	0.137	0.137
Cool Beam, vapor comp.	0.315	0.323	0.289	0.295	0.301	0.335	0.349	0.302
Vapor Compression - VAV	**0.253**	**0.253**	**0.220**	**0.220**	**0.232**	**0.270**	**0.294**	**0.178**

Appendix B
Results for 12 Hour Occupancy with 100% Outside Air

Typical Design Equipment Power Density (2.5 W/sf)

Displacement Ventilation Supply Air Temperature: 65 deg F

12Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-10.19%	-23.46%	-11.43%	-19.07%	-28.44%	-16.59%	-20.48%	-17.01%
Evap. Pre-Cool, ind/direct on outside air	-20.05%	-39.25%	-29.01%	-33.24%	-48.61%	-33.00%	-35.44%	-33.67%
Displ. Vent., vapor compression	-57.63%	-38.79%	-58.68%	-48.01%	-51.87%	-51.88%	-49.08%	-47.85%
Displ. Vent., w/ CompAC + ind pre-cool	-57.83%	-63.12%	-68.11%	-68.58%	-70.98%	-68.11%	-69.69%	-66.54%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-58.41%	-75.89%	-71.14%	-76.05%	-75.94%	-78.06%	-77.50%	-75.75%
Cool Beam, vapor comp.	50.35%	-24.60%	-3.94%	-22.02%	-17.10%	-40.39%	-33.94%	-31.68%
Vapor Compression - VAV	**2.57**	**6.19**	**4.13**	**5.80**	**5.18**	**7.42**	**7.23**	**6.78**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-20.11%	-25.62%	-33.38%	-20.73%	-26.74%	-42.61%	-25.74%	-26.28%
Evap. Pre-Cool, ind/direct on outside air	-37.40%	-42.39%	-52.29%	-37.95%	-45.82%	-67.54%	-52.76%	-43.87%
Displ. Vent., vapor compression	-48.68%	-34.75%	-24.48%	-37.53%	-29.43%	-20.90%	-20.83%	-34.24%
Displ. Vent., w/ CompAC + ind pre-cool	-68.16%	-65.20%	-86.45%	-61.59%	-60.55%	-64.06%	-59.37%	-59.10%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-78.13%	-78.37%	-79.21%	-76.54%	-77.20%	-81.78%	-79.72%	-66.98%
Cool Beam, vapor comp.	-42.33%	-38.41%	-35.48%	-28.84%	-30.46%	-37.00%	-50.06%	-4.60%
Vapor Compression - VAV	**7.78**	**7.71**	**7.73**	**6.77**	**7.22**	**8.29**	**11.65**	**4.82**

12Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	1.17	2.92	1.93	2.86	1.82	3.47	2.82	2.94
Evap. Pre-Cool, ind/direct on outside air	0.97	2.85	1.66	2.73	1.13	3.39	2.68	2.83
Displ. Vent., vapor compression	1.04	2.90	1.38	2.99	2.53	2.41	2.83	2.46
Displ. Vent., w/ CompAC + ind pre-cool	0.66	1.84	0.86	1.75	1.25	1.89	1.81	1.68
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.42	1.37	0.59	1.32	0.41	1.57	1.26	1.37
Cool Beam, vapor comp.	1.17	1.54	1.21	1.56	1.38	1.35	1.60	1.48
Vapor Compression - VAV	**1.48**	**3.64**	**2.12**	**3.33**	**2.89**	**3.85**	**3.62**	**3.40**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	3.70	3.40	3.04	3.35	2.91	2.42	4.60	2.44
Evap. Pre-Cool, ind/direct on outside air	3.71	3.52	2.97	3.19	2.75	1.85	4.64	2.14
Displ. Vent., vapor compression	2.73	3.31	4.57	3.23	3.34	3.81	4.49	3.10
Displ. Vent., w/ CompAC + ind pre-cool	2.04	2.05	0.42	2.11	2.02	1.95	2.99	1.63
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.83	1.86	1.39	1.66	1.30	0.76	2.66	0.84
Cool Beam, vapor comp.	1.39	1.45	1.68	1.64	1.65	1.54	1.64	1.48
Vapor Compression - VAV	**4.11**	**3.99**	**4.52**	**3.95**	**3.82**	**3.85**	**5.26**	**3.25**

12Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.218	0.184	0.212	0.185	0.224	0.201	0.228	0.216
Evap. Pre-Cool, ind/direct on outside air	0.236	0.149	0.198	0.160	0.259	0.166	0.195	0.179
Displ. Vent., vapor compression	0.116	0.148	0.138	0.114	0.108	0.167	0.145	0.162
Displ. Vent., w/ CompAC + ind pre-cool	0.183	0.141	0.172	0.117	0.132	0.141	0.135	0.152
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.281	0.123	0.224	0.119	0.335	0.117	0.144	0.136
Cool Beam, vapor comp.	0.367	0.343	0.366	0.328	0.343	0.369	0.333	0.352
Vapor Compression - VAV	**0.198**	**0.194**	**0.222**	**0.199**	**0.205**	**0.220**	**0.228**	**0.227**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.191	0.192	0.192	0.181	0.207	0.223	0.211	0.163
Evap. Pre-Cool, ind/direct on outside air	0.149	0.144	0.140	0.149	0.162	0.165	0.133	0.142
Displ. Vent., vapor compression	0.166	0.173	0.145	0.148	0.173	0.195	0.231	0.115
Displ. Vent., w/ CompAC + ind pre-cool	0.138	0.149	0.281	0.139	0.160	0.174	0.177	0.136
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.106	0.102	0.131	0.108	0.144	0.225	0.100	0.214
Cool Beam, vapor comp.	0.365	0.374	0.337	0.334	0.347	0.384	0.397	0.349
Vapor Compression - VAV	**0.216**	**0.221**	**0.195**	**0.196**	**0.216**	**0.246**	**0.253**	**0.169**

Displacement Ventilation Supply Air Temperature: 60°F

12Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-10.19%	-23.46%	-11.43%	-19.07%	-28.44%	-16.59%	-20.48%	-17.01%
Evap. Pre-Cool, ind/direct on outside air	-20.05%	-39.25%	-29.01%	-33.24%	-48.61%	-33.00%	-35.44%	-33.67%
Displ. Vent., vapor compression	-34.84%	-13.03%	-30.44%	-19.80%	-21.14%	-23.78%	-14.88%	-15.98%
Displ. Vent., w/ CompAC + ind pre-cool	-45.64%	-41.23%	-45.74%	-43.83%	-53.40%	-40.14%	-43.64%	-38.30%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-50.23%	-59.03%	-58.00%	-57.78%	-69.06%	-56.58%	-57.84%	-53.72%
Cool Beam, vapor comp.	50.35%	-24.60%	-3.94%	-22.02%	-17.10%	-40.39%	-33.94%	-31.68%
Vapor Compression - VAV	**2.57**	**6.19**	**4.13**	**5.80**	**5.18**	**7.42**	**7.23**	**6.78**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-20.11%	-25.62%	-33.38%	-20.73%	-26.74%	-42.61%	-25.74%	-26.28%
Evap. Pre-Cool, ind/direct on outside air	-37.40%	-42.39%	-52.29%	-37.95%	-45.82%	-67.54%	-52.76%	-43.87%
Displ. Vent., vapor compression	-21.59%	-12.80%	-3.83%	-10.52%	-8.15%	-0.58%	-3.80%	-9.79%
Displ. Vent., w/ CompAC + ind pre-cool	-43.23%	-40.94%	-83.78%	-36.54%	-39.99%	-48.84%	-36.21%	-44.56%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-58.32%	-60.38%	-66.75%	-55.91%	-60.82%	-75.58%	-64.34%	-59.53%
Cool Beam, vapor comp.	-42.33%	-38.41%	-35.48%	-28.84%	-30.46%	-37.00%	-50.06%	-4.60%
Vapor Compression - VAV	**7.78**	**7.71**	**7.73**	**6.77**	**7.22**	**8.29**	**11.65**	**4.82**

12Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	1.17	2.92	1.93	2.86	1.82	3.47	2.82	2.94
Evap. Pre-Cool, ind/direct on outside air	0.97	2.85	1.66	2.73	1.13	3.39	2.68	2.83
Displ. Vent., vapor compression	1.48	3.62	1.87	3.49	3.23	3.21	3.68	3.35
Displ. Vent., w/ CompAC + ind pre-cool	1.10	2.80	1.61	2.71	1.88	3.14	2.71	2.85
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.77	2.65	1.38	2.54	0.86	3.07	2.48	2.66
Cool Beam, vapor comp.	1.17	1.54	1.21	1.56	1.38	1.35	1.60	1.48
Vapor Compression - VAV	**1.48**	**3.64**	**2.12**	**3.33**	**2.89**	**3.85**	**3.62**	**3.40**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	3.70	3.40	3.04	3.35	2.91	2.42	4.60	2.44
Evap. Pre-Cool, ind/direct on outside air	3.71	3.52	2.97	3.19	2.75	1.85	4.64	2.14
Displ. Vent., vapor compression	3.63	3.78	4.94	4.00	3.80	4.30	4.85	3.61
Displ. Vent., w/ CompAC + ind pre-cool	3.44	3.30	0.77	3.33	2.79	2.58	4.50	2.23
Displ. Vent., w/ CompAC + ind/dir pre-cool	3.48	3.43	2.76	3.07	2.58	1.57	4.58	1.81
Cool Beam, vapor comp.	1.39	1.45	1.68	1.64	1.65	1.54	1.64	1.48
Vapor Compression - VAV	**4.11**	**3.99**	**4.52**	**3.95**	**3.82**	**3.85**	**5.26**	**3.25**

12Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.218	0.184	0.212	0.185	0.224	0.201	0.228	0.216
Evap. Pre-Cool, ind/direct on outside air	0.236	0.149	0.198	0.160	0.259	0.166	0.195	0.179
Displ. Vent., vapor compression	0.125	0.168	0.171	0.151	0.139	0.199	0.187	0.192
Displ. Vent., w/ CompAC + ind pre-cool	0.141	0.147	0.155	0.136	0.142	0.159	0.168	0.166
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.185	0.108	0.140	0.109	0.205	0.118	0.138	0.133
Cool Beam, vapor comp.	0.367	0.343	0.366	0.328	0.343	0.369	0.333	0.352
Vapor Compression - VAV	**0.198**	**0.194**	**0.222**	**0.199**	**0.205**	**0.220**	**0.228**	**0.227**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.191	0.192	0.192	0.181	0.207	0.223	0.211	0.163
Evap. Pre-Cool, ind/direct on outside air	0.149	0.144	0.140	0.149	0.162	0.165	0.133	0.142
Displ. Vent., vapor compression	0.190	0.203	0.170	0.171	0.199	0.217	0.259	0.135
Displ. Vent., w/ CompAC + ind pre-cool	0.145	0.157	0.185	0.146	0.177	0.186	0.185	0.134
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.105	0.101	0.105	0.110	0.125	0.146	0.102	0.121
Cool Beam, vapor comp.	0.365	0.374	0.337	0.334	0.347	0.384	0.397	0.349
Vapor Compression - VAV	**0.216**	**0.221**	**0.195**	**0.196**	**0.216**	**0.246**	**0.253**	**0.169**

Typical Operating Equipment Power Density (1.0 W/sf)

Displacement Ventilation Supply Air Temperature: 65°F

12Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-6.68%	-23.13%	-9.77%	-18.67%	-26.97%	-16.21%	-20.54%	-13.97%
Evap. Pre-Cool, ind/direct on outside air	-17.09%	-38.80%	-26.83%	-32.78%	-47.08%	-33.05%	-37.15%	-30.22%
Displ. Vent., vapor compression	-54.42%	-39.70%	-58.72%	-50.16%	-53.58%	-52.92%	-50.81%	-48.32%
Displ. Vent., w/ CompAC + ind pre-cool	-53.09%	-63.20%	-66.70%	-69.13%	-70.33%	-68.92%	-71.11%	-67.67%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-52.92%	-75.61%	-69.23%	-76.04%	-74.24%	-78.58%	-78.93%	-76.24%
Cool Beam, vapor comp.	44.59%	-20.79%	-2.00%	-20.00%	-16.68%	-37.35%	-30.02%	-30.90%
Vapor Compression - VAV	**1.89**	**4.42**	**2.96**	**4.29**	**3.85**	**5.22**	**5.20**	**4.99**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-20.55%	-24.97%	-35.77%	-21.08%	-27.59%	-42.48%	-27.42%	-25.92%
Evap. Pre-Cool, ind/direct on outside air	-37.61%	-42.12%	-53.97%	-37.50%	-46.45%	-67.66%	-54.53%	-42.66%
Displ. Vent., vapor compression	-49.86%	-34.98%	-26.46%	-39.45%	-31.15%	-23.32%	-24.42%	-33.53%
Displ. Vent., w/ CompAC + ind pre-cool	-69.28%	-65.91%	-85.01%	-63.35%	-61.29%	-64.86%	-62.53%	-56.90%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-78.61%	-78.78%	-79.43%	-77.19%	-77.48%	-81.83%	-81.39%	-64.19%
Cool Beam, vapor comp.	-39.23%	-33.45%	-33.95%	-28.56%	-27.26%	-34.55%	-47.70%	-4.50%
Vapor Compression - VAV	**5.51**	**5.39**	**5.73**	**4.95**	**5.29**	**6.14**	**8.46**	**3.64**

12Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	0.91	2.07	1.38	2.13	1.38	2.47	2.12	2.26
Evap. Pre-Cool, ind/direct on outside air	0.71	1.99	1.17	2.02	0.86	2.38	1.97	2.21
Displ. Vent., vapor compression	0.78	2.12	1.01	2.19	1.77	1.71	2.06	1.83
Displ. Vent., w/ CompAC + ind pre-cool	0.52	1.35	0.64	1.32	0.90	1.34	1.33	1.20
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.36	0.97	0.47	0.98	0.37	1.10	0.88	0.97
Cool Beam, vapor comp.	0.97	1.31	1.02	1.35	1.20	1.15	1.40	1.17
Vapor Compression - VAV	**1.13**	**2.67**	**1.54**	**2.53**	**2.17**	**2.76**	**2.71**	**2.62**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.59	2.40	2.25	2.53	2.21	1.89	3.48	1.80
Evap. Pre-Cool, ind/direct on outside air	2.57	2.45	2.10	2.43	2.04	1.39	3.41	1.58
Displ. Vent., vapor compression	1.93	2.41	3.46	2.42	2.49	2.87	3.35	2.35
Displ. Vent., w/ CompAC + ind pre-cool	1.39	1.44	0.36	1.51	1.54	1.52	2.11	1.26
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.22	1.28	0.99	1.20	0.95	0.61	1.83	0.66
Cool Beam, vapor comp.	1.20	1.26	1.48	1.35	1.44	1.36	1.46	1.29
Vapor Compression - VAV	**2.95**	**2.82**	**3.50**	**2.99**	**2.91**	**2.97**	**3.88**	**2.50**

12Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.212	0.184	0.212	0.182	0.221	0.198	0.216	0.203
Evap. Pre-Cool, ind/direct on outside air	0.242	0.152	0.202	0.159	0.260	0.164	0.184	0.168
Displ. Vent., vapor compression	0.120	0.141	0.133	0.109	0.110	0.161	0.137	0.151
Displ. Vent., w/ CompAC + ind pre-cool	0.186	0.135	0.167	0.111	0.138	0.135	0.125	0.144
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.269	0.125	0.213	0.117	0.295	0.113	0.138	0.130
Cool Beam, vapor comp.	0.307	0.299	0.310	0.282	0.291	0.319	0.287	0.316
Vapor Compression - VAV	**0.191**	**0.189**	**0.220**	**0.194**	**0.203**	**0.216**	**0.219**	**0.218**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.190	0.190	0.185	0.174	0.196	0.212	0.204	0.168
Evap. Pre-Cool, ind/direct on outside air	0.150	0.144	0.142	0.143	0.157	0.162	0.130	0.148
Displ. Vent., vapor compression	0.161	0.164	0.138	0.139	0.165	0.186	0.220	0.115
Displ. Vent., w/ CompAC + ind pre-cool	0.137	0.144	0.269	0.135	0.151	0.160	0.173	0.139
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.109	0.101	0.135	0.106	0.141	0.209	0.099	0.220
Cool Beam, vapor comp.	0.315	0.323	0.289	0.295	0.301	0.335	0.349	0.302
Vapor Compression - VAV	**0.213**	**0.218**	**0.187**	**0.189**	**0.207**	**0.236**	**0.249**	**0.166**

Displacement Ventilation Supply Air Temperature: 60°F

12Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-6.68%	-23.13%	-9.77%	-18.67%	-26.97%	-16.21%	-20.54%	-13.97%
Evap. Pre-Cool, ind/direct on outside air	-17.09%	-38.80%	-26.83%	-32.78%	-47.08%	-33.05%	-37.15%	-30.22%
Displ. Vent., vapor compression	-54.42%	-39.70%	-58.72%	-50.16%	-53.58%	-52.92%	-50.81%	-48.32%
Displ. Vent., w/ CompAC + ind pre-cool	-53.09%	-63.20%	-66.70%	-69.13%	-70.33%	-68.92%	-71.11%	-67.67%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-52.92%	-75.61%	-69.23%	-76.04%	-74.24%	-78.58%	-78.93%	-76.24%
Cool Beam, vapor comp.	44.59%	-20.79%	-2.00%	-20.00%	-16.68%	-37.35%	-30.02%	-30.90%
Vapor Compression - VAV	**1.89**	**4.42**	**2.96**	**4.29**	**3.85**	**5.22**	**5.20**	**4.99**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-20.55%	-24.97%	-35.77%	-21.08%	-27.59%	-42.48%	-27.42%	-25.92%
Evap. Pre-Cool, ind/direct on outside air	-37.61%	-42.12%	-53.97%	-37.50%	-46.45%	-67.66%	-54.53%	-42.66%
Displ. Vent., vapor compression	-49.86%	-34.98%	-26.46%	-39.45%	-31.15%	-23.32%	-24.42%	-33.53%
Displ. Vent., w/ CompAC + ind pre-cool	-69.28%	-65.91%	-85.01%	-63.35%	-61.29%	-64.86%	-62.53%	-56.90%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-78.61%	-78.78%	-79.43%	-77.19%	-77.48%	-81.83%	-81.39%	-64.19%
Cool Beam, vapor comp.	-39.23%	-33.45%	-33.95%	-28.56%	-27.26%	-34.55%	-47.70%	-4.50%
Vapor Compression - VAV	**5.51**	**5.39**	**5.73**	**4.95**	**5.29**	**6.14**	**8.46**	**3.64**

12Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	0.91	2.07	1.38	2.13	1.38	2.47	2.12	2.26
Evap. Pre-Cool, ind/direct on outside air	0.71	1.99	1.17	2.02	0.86	2.38	1.97	2.21
Displ. Vent., vapor compression	0.78	2.12	1.01	2.19	1.77	1.71	2.06	1.83
Displ. Vent., w/ CompAC + ind pre-cool	0.52	1.35	0.64	1.32	0.90	1.34	1.33	1.20
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.36	0.97	0.47	0.98	0.37	1.10	0.88	0.97
Cool Beam, vapor comp.	0.97	1.31	1.02	1.35	1.20	1.15	1.40	1.17
Vapor Compression - VAV	**1.13**	**2.67**	**1.54**	**2.53**	**2.17**	**2.76**	**2.71**	**2.62**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.59	2.40	2.25	2.53	2.21	1.89	3.48	1.80
Evap. Pre-Cool, ind/direct on outside air	2.57	2.45	2.10	2.43	2.04	1.39	3.41	1.58
Displ. Vent., vapor compression	1.93	2.41	3.46	2.42	2.49	2.87	3.35	2.35
Displ. Vent., w/ CompAC + ind pre-cool	1.39	1.44	0.36	1.51	1.54	1.52	2.11	1.26
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.22	1.28	0.99	1.20	0.95	0.61	1.83	0.66
Cool Beam, vapor comp.	1.20	1.26	1.48	1.35	1.44	1.36	1.46	1.29
Vapor Compression - VAV	**2.95**	**2.82**	**3.50**	**2.99**	**2.91**	**2.97**	**3.88**	**2.50**

12Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.212	0.184	0.212	0.182	0.221	0.198	0.216	0.203
Evap. Pre-Cool, ind/direct on outside air	0.242	0.152	0.202	0.159	0.260	0.164	0.184	0.168
Displ. Vent., vapor compression	0.120	0.141	0.133	0.109	0.110	0.161	0.137	0.151
Displ. Vent., w/ CompAC + ind pre-cool	0.186	0.135	0.167	0.111	0.138	0.135	0.125	0.144
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.269	0.125	0.213	0.117	0.295	0.113	0.138	0.130
Cool Beam, vapor comp.	0.307	0.299	0.310	0.282	0.291	0.319	0.287	0.316
Vapor Compression - VAV	**0.191**	**0.189**	**0.220**	**0.194**	**0.203**	**0.216**	**0.219**	**0.218**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.190	0.190	0.185	0.174	0.196	0.212	0.204	0.168
Evap. Pre-Cool, ind/direct on outside air	0.150	0.144	0.142	0.143	0.157	0.162	0.130	0.148
Displ. Vent., vapor compression	0.161	0.164	0.138	0.139	0.165	0.186	0.220	0.115
Displ. Vent., w/ CompAC + ind pre-cool	0.137	0.144	0.269	0.135	0.151	0.160	0.173	0.139
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.109	0.101	0.135	0.106	0.141	0.209	0.099	0.220
Cool Beam, vapor comp.	0.315	0.323	0.289	0.295	0.301	0.335	0.349	0.302
Vapor Compression - VAV	**0.213**	**0.218**	**0.187**	**0.189**	**0.207**	**0.236**	**0.249**	**0.166**

Appendix C
Results for 24 Hour Occupancy with Economizer

Typical Design Equipment Power Density (2.5 W/sf)

Displacement Ventilation Supply Air Temperature: 65 deg F

24Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-5.94%	-8.31%	-5.90%	-5.27%	-10.74%	-3.62%	6.58%	-1.64%
Evap. Pre-Cool, ind/direct on outside air	-13.25%	-19.87%	-19.33%	-19.91%	-22.86%	-18.16%	-9.12%	-14.70%
Displ. Vent., vapor compression	-56.93%	-35.74%	-60.05%	-51.60%	-50.13%	-44.62%	-48.00%	-45.20%
Displ. Vent., w/ CompAC + ind pre-cool	-50.58%	-52.31%	-63.99%	-61.69%	-59.14%	-58.65%	-60.92%	-58.45%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-48.72%	-59.66%	-65.27%	-66.64%	-61.21%	-67.46%	-67.25%	-65.03%
Cool Beam, vapor comp.	68.87%	20.84%	12.51%	11.21%	25.23%	-8.46%	-5.36%	-0.33%
Vapor Compression - VAV	**3.27**	**5.44**	**5.04**	**5.85**	**4.85**	**6.94**	**7.30**	**6.65**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-8.68%	-9.04%	-15.44%	-7.37%	-11.32%	-25.84%	-15.11%	-13.65%
Evap. Pre-Cool, ind/direct on outside air	-20.17%	-18.26%	-28.84%	-21.30%	-24.12%	-39.56%	-28.34%	-27.44%
Displ. Vent., vapor compression	-40.32%	-33.22%	-22.39%	-35.68%	-25.80%	-16.66%	-15.91%	-30.60%
Displ. Vent., w/ CompAC + ind pre-cool	-57.22%	-54.32%	-74.16%	-52.47%	-50.13%	-54.84%	-46.95%	-49.54%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-64.97%	-62.18%	-61.45%	-61.76%	-60.38%	-66.69%	-58.88%	-54.70%
Cool Beam, vapor comp.	-6.80%	3.40%	12.22%	13.49%	11.92%	4.42%	-10.28%	47.86%
Vapor Compression - VAV	**6.89**	**6.54**	**6.40**	**5.94**	**6.45**	**7.06**	**8.89**	**4.52**

24Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	1.13	1.93	1.57	1.93	1.34	2.04	2.25	2.01
Evap. Pre-Cool, ind/direct on outside air	0.96	1.93	1.45	1.88	1.23	1.97	2.26	1.98
Displ. Vent., vapor compression	0.98	1.86	1.32	1.91	1.62	1.80	1.75	1.79
Displ. Vent., w/ CompAC + ind pre-cool	0.62	1.44	0.80	1.39	0.87	1.53	1.39	1.45
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.39	1.44	0.55	1.35	0.64	1.45	1.28	1.41
Cool Beam, vapor comp.	1.15	1.47	1.19	1.53	1.34	1.33	1.57	1.45
Vapor Compression - VAV	**1.52**	**1.94**	**1.65**	**1.98**	**1.65**	**1.95**	**1.95**	**1.92**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.08	1.97	1.97	2.10	2.04	1.74	2.39	1.71
Evap. Pre-Cool, ind/direct on outside air	2.12	2.10	1.96	2.05	2.02	1.67	2.39	1.64
Displ. Vent., vapor compression	1.95	1.89	2.28	1.99	2.01	2.09	2.24	1.91
Displ. Vent., w/ CompAC + ind pre-cool	1.64	1.47	0.39	1.64	1.56	1.36	1.94	1.17
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.58	1.59	1.49	1.56	1.52	1.14	1.93	1.02
Cool Beam, vapor comp.	1.36	1.42	1.64	1.52	1.61	1.52	1.62	1.45
Vapor Compression - VAV	**2.01**	**1.98**	**2.13**	**2.06**	**2.07**	**1.97**	**2.28**	**1.85**

24Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.300	0.287	0.333	0.319	0.352	0.365	0.380	0.361
Evap. Pre-Cool, ind/direct on outside air	0.324	0.250	0.309	0.276	0.331	0.319	0.324	0.318
Displ. Vent., vapor compression	0.158	0.209	0.168	0.165	0.163	0.237	0.240	0.226
Displ. Vent., w/ CompAC + ind pre-cool	0.287	0.201	0.249	0.179	0.247	0.208	0.226	0.211
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.469	0.169	0.350	0.160	0.321	0.172	0.205	0.183
Cool Beam, vapor comp.	0.530	0.496	0.526	0.471	0.494	0.530	0.486	0.505
Vapor Compression - VAV	**0.245**	**0.320**	**0.349**	**0.337**	**0.336**	**0.407**	**0.427**	**0.396**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.336	0.336	0.306	0.291	0.312	0.336	0.354	0.252
Evap. Pre-Cool, ind/direct on outside air	0.288	0.283	0.260	0.254	0.270	0.285	0.298	0.221
Displ. Vent., vapor compression	0.234	0.257	0.243	0.214	0.265	0.314	0.374	0.181
Displ. Vent., w/ CompAC + ind pre-cool	0.200	0.226	0.469	0.192	0.230	0.262	0.273	0.215
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.169	0.173	0.185	0.162	0.187	0.229	0.212	0.221
Cool Beam, vapor comp.	0.525	0.531	0.488	0.493	0.499	0.543	0.552	0.510
Vapor Compression - VAV	**0.391**	**0.377**	**0.343**	**0.330**	**0.355**	**0.408**	**0.444**	**0.278**

Displacement Ventilation Supply Air Temperature: 60°F

24Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-5.94%	-8.31%	-5.90%	-5.27%	-10.74%	-3.62%	6.58%	-1.64%
Evap. Pre-Cool, ind/direct on outside air	-13.25%	-19.87%	-19.33%	-19.91%	-22.86%	-18.16%	-9.12%	-14.70%
Displ. Vent., vapor compression	-42.39%	-14.04%	-32.12%	-25.02%	-28.66%	-14.57%	-6.23%	-16.91%
Displ. Vent., w/ CompAC + ind pre-cool	-42.88%	-32.42%	-43.71%	-38.99%	-44.44%	-31.16%	-25.10%	-32.80%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-44.26%	-43.98%	-54.76%	-50.41%	-53.74%	-46.09%	-42.15%	-43.31%
Cool Beam, vapor comp.	68.87%	20.84%	12.51%	11.21%	25.23%	-8.46%	-5.36%	-0.33%
Vapor Compression - VAV	**3.27**	**5.44**	**5.04**	**5.85**	**4.85**	**6.94**	**7.30**	**6.65**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-8.68%	-9.04%	-15.44%	-7.37%	-11.32%	-25.84%	-15.11%	-13.65%
Evap. Pre-Cool, ind/direct on outside air	-20.17%	-18.26%	-28.84%	-21.30%	-24.12%	-39.56%	-28.34%	-27.44%
Displ. Vent., vapor compression	-16.30%	-7.41%	-3.95%	-12.90%	-5.59%	0.77%	1.98%	-11.80%
Displ. Vent., w/ CompAC + ind pre-cool	-35.24%	-28.17%	-71.92%	-30.39%	-29.12%	-38.22%	-26.44%	-33.93%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-45.00%	-40.58%	-47.05%	-45.06%	-43.20%	-53.91%	-41.39%	-45.13%
Cool Beam, vapor comp.	-6.80%	3.40%	12.22%	13.49%	11.92%	4.42%	-10.28%	47.86%
Vapor Compression - VAV	**6.89**	**6.54**	**6.40**	**5.94**	**6.45**	**7.06**	**8.89**	**4.52**

24Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	1.13	1.93	1.57	1.93	1.34	2.04	2.25	2.01
Evap. Pre-Cool, ind/direct on outside air	0.96	1.93	1.45	1.88	1.23	1.97	2.26	1.98
Displ. Vent., vapor compression	1.43	2.19	1.77	2.24	1.91	2.20	2.53	2.16
Displ. Vent., w/ CompAC + ind pre-cool	1.05	2.00	1.52	2.00	1.30	2.12	2.43	2.02
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.71	2.03	1.28	1.95	1.15	2.07	2.29	2.02
Cool Beam, vapor comp.	1.15	1.47	1.19	1.53	1.34	1.33	1.57	1.45
Vapor Compression - VAV	**1.52**	**1.94**	**1.65**	**1.98**	**1.65**	**1.95**	**1.95**	**1.92**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.08	1.97	1.97	2.10	2.04	1.74	2.39	1.71
Evap. Pre-Cool, ind/direct on outside air	2.12	2.10	1.96	2.05	2.02	1.67	2.39	1.64
Displ. Vent., vapor compression	2.26	2.25	2.53	2.35	2.37	2.36	2.58	2.20
Displ. Vent., w/ CompAC + ind pre-cool	2.16	2.12	0.71	2.22	2.14	1.83	2.53	1.75
Displ. Vent., w/ CompAC + ind/dir pre-cool	2.22	2.30	2.08	2.18	2.14	1.72	2.60	1.68
Cool Beam, vapor comp.	1.36	1.42	1.64	1.52	1.61	1.52	1.62	1.45
Vapor Compression - VAV	**2.01**	**1.98**	**2.13**	**2.06**	**2.07**	**1.97**	**2.28**	**1.85**

24Hr w/ Econo., 2.5 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.300	0.287	0.333	0.319	0.352	0.365	0.380	0.361
Evap. Pre-Cool, ind/direct on outside air	0.324	0.250	0.309	0.276	0.331	0.319	0.324	0.318
Displ. Vent., vapor compression	0.145	0.237	0.213	0.217	0.198	0.300	0.298	0.284
Displ. Vent., w/ CompAC + ind pre-cool	0.196	0.204	0.206	0.198	0.225	0.250	0.248	0.245
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.280	0.166	0.196	0.165	0.213	0.200	0.203	0.207
Cool Beam, vapor comp.	0.530	0.496	0.526	0.471	0.494	0.530	0.486	0.505
Vapor Compression - VAV	**0.245**	**0.320**	**0.349**	**0.337**	**0.336**	**0.407**	**0.427**	**0.396**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.336	0.336	0.306	0.291	0.312	0.336	0.354	0.252
Evap. Pre-Cool, ind/direct on outside air	0.288	0.283	0.260	0.254	0.270	0.285	0.298	0.221
Displ. Vent., vapor compression	0.283	0.299	0.271	0.245	0.286	0.337	0.393	0.201
Displ. Vent., w/ CompAC + ind pre-cool	0.229	0.247	0.280	0.207	0.238	0.266	0.290	0.189
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.189	0.188	0.182	0.167	0.191	0.211	0.225	0.163
Cool Beam, vapor comp.	0.525	0.531	0.488	0.493	0.499	0.543	0.552	0.510
Vapor Compression - VAV	**0.391**	**0.377**	**0.343**	**0.330**	**0.355**	**0.408**	**0.444**	**0.278**

Typical Operating Equipment Power Density (1.0 W/sf)

Displacement Ventilation Supply Air Temperature: 65°F

24Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-2.86%	-8.33%	-5.78%	-7.77%	-10.21%	-4.61%	-3.26%	-5.50%
Evap. Pre-Cool, ind/direct on outside air	-10.14%	-20.28%	-18.91%	-19.60%	-22.61%	-18.64%	-17.65%	-17.61%
Displ. Vent., vapor compression	-55.96%	-38.10%	-61.11%	-52.69%	-50.70%	-46.70%	-52.04%	-47.02%
Displ. Vent., w/ CompAC + ind pre-cool	-50.00%	-54.53%	-64.77%	-62.98%	-59.36%	-60.30%	-64.54%	-60.27%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-48.21%	-61.90%	-65.85%	-67.71%	-61.15%	-69.05%	-70.73%	-66.63%
Cool Beam, vapor comp.	58.27%	17.92%	8.09%	8.67%	19.62%	-9.49%	-6.80%	-5.58%
Vapor Compression - VAV	**2.39**	**4.09**	**3.76**	**4.45**	**3.67**	**5.19**	**5.59**	**4.97**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-8.12%	-11.77%	-16.24%	-7.32%	-11.46%	-26.43%	-16.21%	-12.07%
Evap. Pre-Cool, ind/direct on outside air	-20.23%	-20.04%	-30.51%	-21.74%	-25.12%	-41.76%	-30.70%	-26.11%
Displ. Vent., vapor compression	-44.28%	-35.79%	-23.71%	-38.04%	-28.32%	-18.72%	-18.26%	-31.66%
Displ. Vent., w/ CompAC + ind pre-cool	-60.02%	-56.57%	-75.12%	-54.68%	-52.32%	-56.84%	-49.85%	-49.93%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-66.65%	-64.68%	-64.18%	-64.01%	-63.03%	-69.53%	-63.38%	-55.03%
Cool Beam, vapor comp.	-9.17%	2.80%	10.89%	11.36%	11.58%	4.99%	-8.57%	40.13%
Vapor Compression - VAV	**5.22**	**4.87**	**4.89**	**4.47**	**4.88**	**5.41**	**6.86**	**3.54**

24Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	0.88	1.51	1.20	1.54	1.05	1.61	1.58	1.55
Evap. Pre-Cool, ind/direct on outside air	0.75	1.49	1.14	1.51	0.95	1.56	1.57	1.53
Displ. Vent., vapor compression	0.75	1.42	0.97	1.47	1.20	1.35	1.29	1.37
Displ. Vent., w/ CompAC + ind pre-cool	0.50	1.07	0.61	1.07	0.67	1.15	1.00	1.09
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.34	1.04	0.44	1.01	0.44	1.06	0.83	1.04
Cool Beam, vapor comp.	0.96	1.28	1.02	1.34	1.17	1.13	1.37	1.15
Vapor Compression - VAV	**1.10**	**1.56**	**1.30**	**1.62**	**1.32**	**1.57**	**1.60**	**1.55**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	1.66	1.54	1.58	1.66	1.63	1.38	1.92	1.36
Evap. Pre-Cool, ind/direct on outside air	1.67	1.61	1.54	1.62	1.60	1.30	1.91	1.30
Displ. Vent., vapor compression	1.40	1.41	1.83	1.53	1.56	1.67	1.78	1.49
Displ. Vent., w/ CompAC + ind pre-cool	1.16	1.08	0.34	1.25	1.20	1.05	1.50	0.92
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.16	1.14	1.11	1.17	1.14	0.82	1.45	0.75
Cool Beam, vapor comp.	1.17	1.23	1.45	1.33	1.41	1.34	1.41	1.26
Vapor Compression - VAV	**1.63**	**1.60**	**1.76**	**1.67**	**1.69**	**1.62**	**1.89**	**1.51**

24Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.288	0.274	0.324	0.293	0.339	0.338	0.380	0.331
Evap. Pre-Cool, ind/direct on outside air	0.311	0.241	0.292	0.261	0.323	0.298	0.326	0.293
Displ. Vent., vapor compression	0.154	0.197	0.165	0.158	0.163	0.226	0.231	0.210
Displ. Vent., w/ CompAC + ind pre-cool	0.263	0.191	0.237	0.170	0.241	0.197	0.221	0.198
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.392	0.165	0.318	0.156	0.348	0.166	0.218	0.174
Cool Beam, vapor comp.	0.431	0.414	0.438	0.398	0.408	0.456	0.421	0.449
Vapor Compression - VAV	**0.249**	**0.300**	**0.330**	**0.313**	**0.316**	**0.378**	**0.400**	**0.366**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.319	0.308	0.288	0.276	0.293	0.322	0.335	0.251
Evap. Pre-Cool, ind/direct on outside air	0.274	0.266	0.244	0.240	0.253	0.269	0.278	0.221
Displ. Vent., vapor compression	0.229	0.245	0.226	0.201	0.249	0.293	0.352	0.178
Displ. Vent., w/ CompAC + ind pre-cool	0.198	0.216	0.392	0.179	0.214	0.247	0.256	0.212
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.166	0.167	0.176	0.152	0.175	0.222	0.193	0.234
Cool Beam, vapor comp.	0.448	0.451	0.417	0.413	0.427	0.473	0.496	0.431
Vapor Compression - VAV	**0.365**	**0.348**	**0.316**	**0.305**	**0.328**	**0.382**	**0.414**	**0.267**

Displacement Ventilation Supply Air Temperature: 60°F

24Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-2.86%	-8.33%	-5.78%	-7.77%	-10.21%	-4.61%	-3.26%	-5.50%
Evap. Pre-Cool, ind/direct on outside air	-10.14%	-20.28%	-18.91%	-19.60%	-22.61%	-18.64%	-17.65%	-17.61%
Displ. Vent., vapor compression	-55.96%	-38.10%	-61.11%	-52.69%	-50.70%	-46.70%	-52.04%	-47.02%
Displ. Vent., w/ CompAC + ind pre-cool	-50.00%	-54.53%	-64.77%	-62.98%	-59.36%	-60.30%	-64.54%	-60.27%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-48.21%	-61.90%	-65.85%	-67.71%	-61.15%	-69.05%	-70.73%	-66.63%
Cool Beam, vapor comp.	58.27%	17.92%	8.09%	8.67%	19.62%	-9.49%	-6.80%	-5.58%
Vapor Compression - VAV	**2.39**	**4.09**	**3.76**	**4.45**	**3.67**	**5.19**	**5.59**	**4.97**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-8.12%	-11.77%	-16.24%	-7.32%	-11.46%	-26.43%	-16.21%	-12.07%
Evap. Pre-Cool, ind/direct on outside air	-20.23%	-20.04%	-30.51%	-21.74%	-25.12%	-41.76%	-30.70%	-26.11%
Displ. Vent., vapor compression	-44.28%	-35.79%	-23.71%	-38.04%	-28.32%	-18.72%	-18.26%	-31.66%
Displ. Vent., w/ CompAC + ind pre-cool	-60.02%	-56.57%	-75.12%	-54.68%	-52.32%	-56.84%	-49.85%	-49.93%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-66.65%	-64.68%	-64.18%	-64.01%	-63.03%	-69.53%	-63.38%	-55.03%
Cool Beam, vapor comp.	-9.17%	2.80%	10.89%	11.36%	11.58%	4.99%	-8.57%	40.13%
Vapor Compression - VAV	**5.22**	**4.87**	**4.89**	**4.47**	**4.88**	**5.41**	**6.86**	**3.54**

24Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	0.88	1.51	1.20	1.54	1.05	1.61	1.58	1.55
Evap. Pre-Cool, ind/direct on outside air	0.75	1.49	1.14	1.51	0.95	1.56	1.57	1.53
Displ. Vent., vapor compression	0.75	1.42	0.97	1.47	1.20	1.35	1.29	1.37
Displ. Vent., w/ CompAC + ind pre-cool	0.50	1.07	0.61	1.07	0.67	1.15	1.00	1.09
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.34	1.04	0.44	1.01	0.44	1.06	0.83	1.04
Cool Beam, vapor comp.	0.96	1.28	1.02	1.34	1.17	1.13	1.37	1.15
Vapor Compression - VAV	**1.10**	**1.56**	**1.30**	**1.62**	**1.32**	**1.57**	**1.60**	**1.55**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	1.66	1.54	1.58	1.66	1.63	1.38	1.92	1.36
Evap. Pre-Cool, ind/direct on outside air	1.67	1.61	1.54	1.62	1.60	1.30	1.91	1.30
Displ. Vent., vapor compression	1.40	1.41	1.83	1.53	1.56	1.67	1.78	1.49
Displ. Vent., w/ CompAC + ind pre-cool	1.16	1.08	0.34	1.25	1.20	1.05	1.50	0.92
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.16	1.14	1.11	1.17	1.14	0.82	1.45	0.75
Cool Beam, vapor comp.	1.17	1.23	1.45	1.33	1.41	1.34	1.41	1.26
Vapor Compression - VAV	**1.63**	**1.60**	**1.76**	**1.67**	**1.69**	**1.62**	**1.89**	**1.51**

24Hr w/ Econo., 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.288	0.274	0.324	0.293	0.339	0.338	0.380	0.331
Evap. Pre-Cool, ind/direct on outside air	0.311	0.241	0.292	0.261	0.323	0.298	0.326	0.293
Displ. Vent., vapor compression	0.154	0.197	0.165	0.158	0.163	0.226	0.231	0.210
Displ. Vent., w/ CompAC + ind pre-cool	0.263	0.191	0.237	0.170	0.241	0.197	0.221	0.198
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.392	0.165	0.318	0.156	0.348	0.166	0.218	0.174
Cool Beam, vapor comp.	0.431	0.414	0.438	0.398	0.408	0.456	0.421	0.449
Vapor Compression - VAV	**0.249**	**0.300**	**0.330**	**0.313**	**0.316**	**0.378**	**0.400**	**0.366**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.319	0.308	0.288	0.276	0.293	0.322	0.335	0.251
Evap. Pre-Cool, ind/direct on outside air	0.274	0.266	0.244	0.240	0.253	0.269	0.278	0.221
Displ. Vent., vapor compression	0.229	0.245	0.226	0.201	0.249	0.293	0.352	0.178
Displ. Vent., w/ CompAC + ind pre-cool	0.198	0.216	0.392	0.179	0.214	0.247	0.256	0.212
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.166	0.167	0.176	0.152	0.175	0.222	0.193	0.234
Cool Beam, vapor comp.	0.448	0.451	0.417	0.413	0.427	0.473	0.496	0.431
Vapor Compression - VAV	**0.365**	**0.348**	**0.316**	**0.305**	**0.328**	**0.382**	**0.414**	**0.267**

Appendix D
Results for 24 Hour Occupancy with 100% Outside Air

Typical Design Equipment Power Density (2.5 W/sf)

Displacement Ventilation Supply Air Temperature: 65 deg F

24Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh	% change vs VAV kWh
Evap. Pre-Cool, indirect on outside air	-4.23%	-18.99%	-8.18%	-15.08%	-22.20%	-14.16%	-18.78%	-15.79%
Evap. Pre-Cool, ind/direct on outside air	-11.66%	-34.46%	-24.43%	-28.20%	-40.36%	-29.69%	-33.16%	-30.46%
Displ. Vent., vapor compression	-47.54%	-42.26%	-59.77%	-53.01%	-51.33%	-56.29%	-53.12%	-52.57%
Displ. Vent., w/ CompAC + ind pre-cool	-44.60%	-61.39%	-64.69%	-67.32%	-63.44%	-69.16%	-69.58%	-67.45%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-43.96%	-70.96%	-66.25%	-72.46%	-66.42%	-76.97%	-76.39%	-74.19%
Cool Beam, vapor comp.	50.76%	-18.05%	-4.77%	-20.06%	-9.99%	-38.83%	-33.25%	-28.39%
Vapor Compression - VAV	**3.68**	**8.08**	**6.00**	**8.18**	**6.81**	**10.45**	**10.47**	**9.30**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-18.00%	-20.81%	-31.26%	-18.28%	-25.17%	-40.20%	-29.24%	-22.96%
Evap. Pre-Cool, ind/direct on outside air	-32.99%	-35.51%	-49.22%	-34.75%	-43.22%	-64.77%	-55.05%	-39.52%
Displ. Vent., vapor compression	-53.01%	-40.14%	-27.41%	-43.77%	-31.80%	-21.49%	-25.56%	-34.30%
Displ. Vent., w/ CompAC + ind pre-cool	-68.66%	-64.33%	-81.04%	-63.33%	-60.39%	-63.70%	-62.58%	-54.65%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-76.13%	-75.09%	-76.75%	-74.19%	-74.61%	-78.83%	-79.79%	-60.53%
Cool Beam, vapor comp.	-38.93%	-31.50%	-32.74%	-26.18%	-25.21%	-33.82%	-49.88%	-3.84%
Vapor Compression - VAV	**10.57**	**9.91**	**10.68**	**9.17**	**9.67**	**11.17**	**15.45**	**6.91**

24Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 65° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	1.13	2.73	1.83	2.76	1.73	3.26	2.62	2.75
Evap. Pre-Cool, ind/direct on outside air	0.92	2.65	1.56	2.62	1.06	3.15	2.44	2.64
Displ. Vent., vapor compression	0.96	2.73	1.30	2.84	2.25	2.27	2.57	2.32
Displ. Vent., w/ CompAC + ind pre-cool	0.60	1.70	0.80	1.67	1.11	1.77	1.62	1.54
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.38	1.20	0.54	1.25	0.38	1.45	1.08	1.21
Cool Beam, vapor comp.	1.15	1.47	1.19	1.53	1.34	1.33	1.57	1.45
Vapor Compression - VAV	**1.43**	**3.43**	**2.02**	**3.22**	**2.75**	**3.63**	**3.38**	**3.21**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	3.37	3.12	2.92	3.26	2.73	2.29	4.15	2.33
Evap. Pre-Cool, ind/direct on outside air	3.37	3.21	2.84	3.13	2.51	1.75	4.13	2.03
Displ. Vent., vapor compression	2.50	2.95	4.39	3.04	3.19	3.63	4.27	2.87
Displ. Vent., w/ CompAC + ind pre-cool	1.80	1.87	0.38	1.93	1.90	1.82	2.69	1.49
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.57	1.66	1.33	1.52	1.12	0.71	2.33	0.78
Cool Beam, vapor comp.	1.36	1.42	1.64	1.52	1.61	1.52	1.62	1.45
Vapor Compression - VAV	**3.86**	**3.68**	**4.34**	**3.85**	**3.64**	**3.69**	**4.90**	**3.10**

24Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.342	0.264	0.331	0.278	0.331	0.304	0.354	0.313
Evap. Pre-Cool, ind/direct on outside air	0.386	0.220	0.318	0.247	0.415	0.258	0.312	0.270
Displ. Vent., vapor compression	0.221	0.188	0.203	0.150	0.159	0.222	0.208	0.210
Displ. Vent., w/ CompAC + ind pre-cool	0.373	0.202	0.292	0.177	0.243	0.201	0.214	0.216
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.592	0.215	0.407	0.199	0.654	0.183	0.250	0.219
Cool Beam, vapor comp.	0.530	0.496	0.526	0.471	0.494	0.530	0.486	0.505
Vapor Compression - VAV	**0.294**	**0.269**	**0.339**	**0.290**	**0.283**	**0.328**	**0.354**	**0.331**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.284	0.278	0.281	0.255	0.295	0.325	0.304	0.254
Evap. Pre-Cool, ind/direct on outside air	0.232	0.220	0.213	0.212	0.243	0.251	0.194	0.229
Displ. Vent., vapor compression	0.220	0.223	0.197	0.188	0.229	0.269	0.311	0.176
Displ. Vent., w/ CompAC + ind pre-cool	0.203	0.210	0.592	0.193	0.224	0.247	0.248	0.234
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.177	0.165	0.209	0.173	0.243	0.369	0.154	0.386
Cool Beam, vapor comp.	0.525	0.531	0.488	0.493	0.499	0.543	0.552	0.510
Vapor Compression - VAV	**0.313**	**0.307**	**0.281**	**0.272**	**0.304**	**0.346**	**0.360**	**0.255**

Displacement Ventilation Supply Air Temperature: 60°F

24Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-4.23%	-18.99%	-8.18%	-15.08%	-22.20%	-14.16%	-18.78%	-15.79%
Evap. Pre-Cool, ind/direct on outside air	-11.66%	-34.46%	-24.43%	-28.20%	-40.36%	-29.69%	-33.16%	-30.46%
Displ. Vent., vapor compression	-37.69%	-18.85%	-36.29%	-26.57%	-29.78%	-27.70%	-20.45%	-22.28%
Displ. Vent., w/ CompAC + ind pre-cool	-42.41%	-43.86%	-48.64%	-46.85%	-52.86%	-43.52%	-46.55%	-42.45%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-44.78%	-59.67%	-58.45%	-59.06%	-64.36%	-58.25%	-58.84%	-55.37%
Cool Beam, vapor comp.	50.76%	-18.05%	-4.77%	-20.06%	-9.99%	-38.83%	-33.25%	-28.39%
Vapor Compression - VAV	**3.68**	**8.08**	**6.00**	**8.18**	**6.81**	**10.45**	**10.47**	**9.30**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-18.00%	-20.81%	-31.26%	-18.28%	-25.17%	-40.20%	-29.24%	-22.96%
Evap. Pre-Cool, ind/direct on outside air	-32.99%	-35.51%	-49.22%	-34.75%	-43.22%	-64.77%	-55.05%	-39.52%
Displ. Vent., vapor compression	-24.17%	-15.63%	-7.73%	-18.10%	-11.60%	-2.38%	-9.44%	-14.24%
Displ. Vent., w/ CompAC + ind pre-cool	-45.19%	-42.47%	-81.32%	-41.48%	-43.03%	-50.92%	-42.04%	-45.67%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-58.57%	-59.54%	-67.45%	-59.42%	-62.71%	-75.95%	-68.13%	-58.01%
Cool Beam, vapor comp.	-38.93%	-31.50%	-32.74%	-26.18%	-25.21%	-33.82%	-49.88%	-3.84%
Vapor Compression - VAV	**10.57**	**9.91**	**10.68**	**9.17**	**9.67**	**11.17**	**15.45**	**6.91**

24Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	1.13	2.73	1.83	2.76	1.73	3.26	2.62	2.75
Evap. Pre-Cool, ind/direct on outside air	0.92	2.65	1.56	2.62	1.06	3.15	2.44	2.64
Displ. Vent., vapor compression	1.42	3.47	1.82	3.41	2.94	3.24	3.43	3.24
Displ. Vent., w/ CompAC + ind pre-cool	1.05	2.66	1.52	2.66	1.68	3.06	2.47	2.67
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.71	2.47	1.29	2.43	0.78	2.94	2.27	2.45
Cool Beam, vapor comp.	1.15	1.47	1.19	1.53	1.34	1.33	1.57	1.45
Vapor Compression - VAV	**1.43**	**3.43**	**2.02**	**3.22**	**2.75**	**3.63**	**3.38**	**3.21**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	3.37	3.12	2.92	3.26	2.73	2.29	4.15	2.33
Evap. Pre-Cool, ind/direct on outside air	3.37	3.21	2.84	3.13	2.51	1.75	4.13	2.03
Displ. Vent., vapor compression	3.70	3.79	4.85	3.90	3.70	4.18	4.71	3.49
Displ. Vent., w/ CompAC + ind pre-cool	3.28	3.13	0.71	3.22	2.57	2.46	4.18	2.09
Displ. Vent., w/ CompAC + ind/dir pre-cool	3.19	3.18	2.64	2.99	2.28	1.49	4.18	1.71
Cool Beam, vapor comp.	1.36	1.42	1.64	1.52	1.61	1.52	1.62	1.45
Vapor Compression - VAV	**3.86**	**3.68**	**4.34**	**3.85**	**3.64**	**3.69**	**4.90**	**3.10**

24Hr w/ 100% OA, 2.5 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.342	0.264	0.331	0.278	0.331	0.304	0.354	0.313
Evap. Pre-Cool, ind/direct on outside air	0.386	0.220	0.318	0.247	0.415	0.258	0.312	0.270
Displ. Vent., vapor compression	0.176	0.208	0.230	0.194	0.176	0.257	0.264	0.245
Displ. Vent., w/ CompAC + ind pre-cool	0.222	0.188	0.222	0.180	0.206	0.213	0.247	0.221
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.314	0.145	0.212	0.152	0.334	0.164	0.207	0.187
Cool Beam, vapor comp.	0.530	0.496	0.526	0.471	0.494	0.530	0.486	0.505
Vapor Compression - VAV	**0.294**	**0.269**	**0.339**	**0.290**	**0.283**	**0.328**	**0.354**	**0.331**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.284	0.278	0.281	0.255	0.295	0.325	0.304	0.254
Evap. Pre-Cool, ind/direct on outside air	0.232	0.220	0.213	0.212	0.243	0.251	0.194	0.229
Displ. Vent., vapor compression	0.239	0.244	0.226	0.213	0.257	0.290	0.343	0.189
Displ. Vent., w/ CompAC + ind pre-cool	0.195	0.202	0.314	0.185	0.238	0.248	0.247	0.200
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.151	0.139	0.147	0.138	0.176	0.201	0.136	0.188
Cool Beam, vapor comp.	0.525	0.531	0.488	0.493	0.499	0.543	0.552	0.510
Vapor Compression - VAV	**0.313**	**0.307**	**0.281**	**0.272**	**0.304**	**0.346**	**0.360**	**0.255**

Typical Operating Equipment Power Density (1.0 W/sf)

Displacement Ventilation Supply Air Temperature: 65°F

24Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-2.79%	-18.98%	-6.23%	-15.21%	-20.49%	-13.22%	-17.68%	-11.80%
Evap. Pre-Cool, ind/direct on outside air	-10.92%	-34.02%	-22.01%	-28.23%	-38.11%	-28.83%	-33.88%	-26.15%
Displ. Vent., vapor compression	-44.62%	-41.97%	-58.64%	-54.05%	-51.47%	-56.24%	-54.74%	-52.07%
Displ. Vent., w/ CompAC + ind pre-cool	-40.73%	-60.55%	-62.53%	-67.01%	-61.58%	-68.89%	-70.25%	-67.40%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-39.67%	-69.60%	-63.72%	-71.72%	-63.72%	-76.43%	-76.60%	-73.64%
Cool Beam, vapor comp.	37.73%	-16.26%	-5.19%	-20.60%	-12.32%	-36.06%	-29.10%	-29.07%
Vapor Compression - VAV	**2.76**	**5.81**	**4.37**	**6.13**	**5.09**	**7.41**	**7.60**	**6.90**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-17.38%	-19.85%	-33.12%	-17.48%	-24.41%	-39.61%	-29.95%	-21.77%
Evap. Pre-Cool, ind/direct on outside air	-32.23%	-34.55%	-50.27%	-33.91%	-43.12%	-64.20%	-55.26%	-37.74%
Displ. Vent., vapor compression	-53.59%	-40.31%	-28.02%	-43.21%	-32.47%	-22.20%	-25.11%	-32.98%
Displ. Vent., w/ CompAC + ind pre-cool	-68.65%	-63.95%	-79.37%	-62.93%	-60.26%	-63.75%	-63.40%	-52.16%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-75.57%	-74.21%	-76.35%	-73.18%	-74.09%	-78.27%	-79.99%	-57.60%
Cool Beam, vapor comp.	-37.20%	-27.74%	-31.32%	-23.60%	-22.70%	-30.78%	-45.39%	-4.91%
Vapor Compression - VAV	**7.61**	**6.98**	**7.93**	**6.57**	**7.08**	**8.24**	**11.26**	**5.23**

24Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Peak Demand (W/sf)	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**	**Peak Demand (W/sf)**
Evap. Pre-Cool, indirect on outside air	0.88	1.93	1.33	2.07	1.30	2.31	1.95	2.13
Evap. Pre-Cool, ind/direct on outside air	0.68	1.83	1.14	1.95	0.84	2.22	1.79	2.07
Displ. Vent., vapor compression	0.72	1.97	0.95	2.06	1.52	1.60	1.77	1.73
Displ. Vent., w/ CompAC + ind pre-cool	0.48	1.22	0.60	1.25	0.74	1.24	1.13	1.11
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.33	0.82	0.44	0.93	0.34	1.00	0.78	0.88
Cool Beam, vapor comp.	0.96	1.28	1.02	1.34	1.17	1.13	1.37	1.15
Vapor Compression - VAV	**1.10**	**2.49**	**1.48**	**2.46**	**2.05**	**2.59**	**2.51**	**2.47**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.43	2.19	2.12	2.35	2.06	1.76	2.97	1.72
Evap. Pre-Cool, ind/direct on outside air	2.41	2.22	1.97	2.23	1.87	1.32	2.92	1.50
Displ. Vent., vapor compression	1.73	2.09	3.27	2.23	2.33	2.72	3.17	2.13
Displ. Vent., w/ CompAC + ind pre-cool	1.28	1.30	0.33	1.39	1.43	1.39	1.88	1.12
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.08	1.12	0.93	1.08	0.85	0.57	1.61	0.63
Cool Beam, vapor comp.	1.17	1.23	1.45	1.33	1.41	1.34	1.41	1.26
Vapor Compression - VAV	**2.79**	**2.59**	**3.31**	**2.78**	**2.73**	**2.80**	**3.62**	**2.38**

24Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 65° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	Annual Load Factor	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**	**Annual Load Factor**
Evap. Pre-Cool, indirect on outside air	0.331	0.266	0.331	0.275	0.331	0.304	0.344	0.300
Evap. Pre-Cool, ind/direct on outside air	0.391	0.229	0.322	0.246	0.399	0.259	0.301	0.258
Displ. Vent., vapor compression	0.229	0.187	0.204	0.150	0.174	0.222	0.209	0.200
Displ. Vent., w/ CompAC + ind pre-cool	0.371	0.205	0.292	0.177	0.280	0.203	0.215	0.213
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.542	0.235	0.390	0.203	0.571	0.190	0.244	0.216
Cool Beam, vapor comp.	0.431	0.414	0.438	0.398	0.408	0.456	0.421	0.449
Vapor Compression - VAV	**0.287**	**0.267**	**0.337**	**0.285**	**0.283**	**0.327**	**0.346**	**0.319**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.283	0.280	0.276	0.254	0.286	0.313	0.303	0.260
Evap. Pre-Cool, ind/direct on outside air	0.234	0.226	0.221	0.214	0.237	0.247	0.197	0.237
Displ. Vent., vapor compression	0.223	0.219	0.193	0.183	0.225	0.261	0.303	0.180
Displ. Vent., w/ CompAC + ind pre-cool	0.204	0.212	0.542	0.192	0.217	0.238	0.249	0.244
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.189	0.176	0.223	0.179	0.239	0.349	0.159	0.385
Cool Beam, vapor comp.	0.448	0.451	0.417	0.413	0.427	0.473	0.496	0.431
Vapor Compression - VAV	**0.312**	**0.307**	**0.273**	**0.270**	**0.296**	**0.336**	**0.355**	**0.251**

Displacement Ventilation Supply Air Temperature: 60°F

24Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 60° F								
T-24 Compliant Construction System Configuration	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
	% change vs VAV kWh	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**	**% change vs VAV kWh**
Evap. Pre-Cool, indirect on outside air	-2.79%	-18.98%	-6.23%	-15.21%	-20.49%	-13.22%	-17.68%	-11.80%
Evap. Pre-Cool, ind/direct on outside air	-10.92%	-34.02%	-22.01%	-28.23%	-38.11%	-28.83%	-33.88%	-26.15%
Displ. Vent., vapor compression	-44.62%	-41.97%	-58.64%	-54.05%	-51.47%	-56.24%	-54.74%	-52.07%
Displ. Vent., w/ CompAC + ind pre-cool	-40.73%	-60.55%	-62.53%	-67.01%	-61.58%	-68.89%	-70.25%	-67.40%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-39.67%	-69.60%	-63.72%	-71.72%	-63.72%	-76.43%	-76.60%	-73.64%
Cool Beam, vapor comp.	37.73%	-16.26%	-5.19%	-20.60%	-12.32%	-36.06%	-29.10%	-29.07%
Vapor Compression - VAV	**2.76**	**5.81**	**4.37**	**6.13**	**5.09**	**7.41**	**7.60**	**6.90**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	-17.38%	-19.85%	-33.12%	-17.48%	-24.41%	-39.61%	-29.95%	-21.77%
Evap. Pre-Cool, ind/direct on outside air	-32.23%	-34.55%	-50.27%	-33.91%	-43.12%	-64.20%	-55.26%	-37.74%
Displ. Vent., vapor compression	-53.59%	-40.31%	-28.02%	-43.21%	-32.47%	-22.20%	-25.11%	-32.98%
Displ. Vent., w/ CompAC + ind pre-cool	-68.65%	-63.95%	-79.37%	-62.93%	-60.26%	-63.75%	-63.40%	-52.16%
Displ. Vent., w/ CompAC + ind/dir pre-cool	-75.57%	-74.21%	-76.35%	-73.18%	-74.09%	-78.27%	-79.99%	-57.60%
Cool Beam, vapor comp.	-37.20%	-27.74%	-31.32%	-23.60%	-22.70%	-30.78%	-45.39%	-4.91%
Vapor Compression - VAV	**7.61**	**6.98**	**7.93**	**6.57**	**7.08**	**8.24**	**11.26**	**5.23**

24Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)	Peak Demand (W/sf)
Evap. Pre-Cool, indirect on outside air	0.88	1.93	1.33	2.07	1.30	2.31	1.95	2.13
Evap. Pre-Cool, ind/direct on outside air	0.68	1.83	1.14	1.95	0.84	2.22	1.79	2.07
Displ. Vent., vapor compression	0.72	1.97	0.95	2.06	1.52	1.60	1.77	1.73
Displ. Vent., w/ CompAC + ind pre-cool	0.48	1.22	0.60	1.25	0.74	1.24	1.13	1.11
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.33	0.82	0.44	0.93	0.34	1.00	0.78	0.88
Cool Beam, vapor comp.	0.96	1.28	1.02	1.34	1.17	1.13	1.37	1.15
Vapor Compression - VAV	**1.10**	**2.49**	**1.48**	**2.46**	**2.05**	**2.59**	**2.51**	**2.47**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	2.43	2.19	2.12	2.35	2.06	1.76	2.97	1.72
Evap. Pre-Cool, ind/direct on outside air	2.41	2.22	1.97	2.23	1.87	1.32	2.92	1.50
Displ. Vent., vapor compression	1.73	2.09	3.27	2.23	2.33	2.72	3.17	2.13
Displ. Vent., w/ CompAC + ind pre-cool	1.28	1.30	0.33	1.39	1.43	1.39	1.88	1.12
Displ. Vent., w/ CompAC + ind/dir pre-cool	1.08	1.12	0.93	1.08	0.85	0.57	1.61	0.63
Cool Beam, vapor comp.	1.17	1.23	1.45	1.33	1.41	1.34	1.41	1.26
Vapor Compression - VAV	**2.79**	**2.59**	**3.31**	**2.78**	**2.73**	**2.80**	**3.62**	**2.38**

24Hr w/ 100% OA, 1.0 W/sf EPD, DV Supply Air 60° F

T-24 Compliant Construction System Configuration	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor	Annual Load Factor
Evap. Pre-Cool, indirect on outside air	0.331	0.266	0.331	0.275	0.331	0.304	0.344	0.300
Evap. Pre-Cool, ind/direct on outside air	0.391	0.229	0.322	0.246	0.399	0.259	0.301	0.258
Displ. Vent., vapor compression	0.229	0.187	0.204	0.150	0.174	0.222	0.209	0.200
Displ. Vent., w/ CompAC + ind pre-cool	0.371	0.205	0.292	0.177	0.280	0.203	0.215	0.213
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.542	0.235	0.390	0.203	0.571	0.190	0.244	0.216
Cool Beam, vapor comp.	0.431	0.414	0.438	0.398	0.408	0.456	0.421	0.449
Vapor Compression - VAV	**0.287**	**0.267**	**0.337**	**0.285**	**0.283**	**0.327**	**0.346**	**0.319**
	CZ9	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Evap. Pre-Cool, indirect on outside air	0.283	0.280	0.276	0.254	0.286	0.313	0.303	0.260
Evap. Pre-Cool, ind/direct on outside air	0.234	0.226	0.221	0.214	0.237	0.247	0.197	0.237
Displ. Vent., vapor compression	0.223	0.219	0.193	0.183	0.225	0.261	0.303	0.180
Displ. Vent., w/ CompAC + ind pre-cool	0.204	0.212	0.542	0.192	0.217	0.238	0.249	0.244
Displ. Vent., w/ CompAC + ind/dir pre-cool	0.189	0.176	0.223	0.179	0.239	0.349	0.159	0.385
Cool Beam, vapor comp.	0.448	0.451	0.417	0.413	0.427	0.473	0.496	0.431
Vapor Compression - VAV	**0.312**	**0.307**	**0.273**	**0.270**	**0.296**	**0.336**	**0.355**	**0.251**